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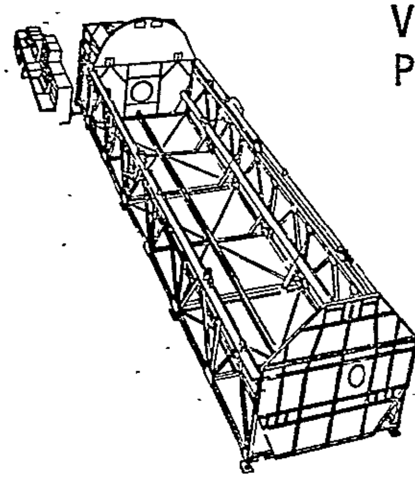
VOLUME II
PART I



SHUTTLE PAYLOAD INTERFACE VERIFICATION EQUIPMENT STUDY
VOLUME II TECHNICAL DOCUMENT - PART I

APRIL 1976

NASA CONTRACT: NAS9-14000 CCA 140 REV. 1

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SHUTTLE PAYLOAD
INTERFACE PROJECTS GROUP

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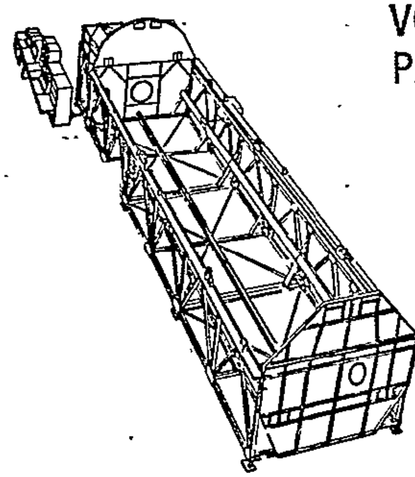

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FOREWORD

This document is a contractual requirement of NAS9-14000, CCA 140 Revision 1 and is provided in response to the contract. The study was conducted by the Space Division of Rockwell International for the Johnson Space Center of the National Aeronautics and Space Administration. It is published in four volumes:

Vol. I	Executive Summary
Vol. II	Technical Document - Part 1 Technical Appendices - Part 2
Vol. III	Specification Data
Vol. IV	Project Plans

TECHNICAL REPORT INDEX/ABSTRACT

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Shuttle Payload Interface Verification Equipment(IVE) Study	
AUTHOR(S)	

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DESCRIPTIVE TERMS

Shuttle	Preliminary Design	Data Management
Payloads	Operators Console	Computer
Spacelab	Mission Station	Heat Exchanger
P/L Interface	On-Orbit Station	Development Plans
P/L Interface Verif.	Payload Station	Schedules
Avionics	Electrical Power	
Payload Integration	Communications	

ABSTRACT

Single and mixed payloads must be integrated into the Shuttle Orbiter within the 160 hour turnaround requirement for the Shuttle system. In order to accomplish this integration process some off-line integration capability is required. This report is a preliminary design analysis of a "stand alone" (no facility GSE support required) payload integration device (IVE) capable of verifying payload compatibility in form, fit and function with the Shuttle Orbiter prior to on-line payload/Orbiter operations. The IVE is a high fidelity replica of the Orbiter payload accommodations capable of supporting payload functional checkout and mission simulation. A top level payload integration analysis developed detailed functional flow block diagrams of the payload integration process for the broad spectrum of P/L's and identified degree of Orbiter data required by the payload user and potential applications of the IVE.

This work was performed for Johnson Space Center of the National Aeronautics and Space Administration under contract NAS9-14000 CCA 140 Rev. 1.

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1.0 SUMMARY

The Space Transportation System (STS) has imposed a 160-hour turn-around time for the Shuttle system. As a result the time allocated for cargo/payload integration during the on-line flow is severly limited; consequently, the on-line payload integration is restricted to the physical mating, continuity check of the electrical interface, a leak check of the fluid interfaces, and final servicing prior to launch.

The emergence of Shuttle cargo consisting of mixed, independent payloads requires the initiation of the integration process with the Orbiter at some point downstream in the payload development process prior to arrival at the launch site.

In order to assure the bringing together of the Shuttle Orbiter and payloads to achieve an acceptable level of mission success with minimum cost and risk to both payloads and STS programs, some off-line payload integration capability (implementation processes and tools) must be developed.

The Interface Verification Equipment (IVE) Study primary objective was to define a low-cost simulation of the Orbiter side of the standard interface to the payloads as described in Shuttle Program Level II document, JSC 07700, Vol. XIV, Space Shuttle System Payload Accommodations, that would meet the off-line Shuttle cargo/payload integration requirements at the launch site (KSC), as well as off-site Shuttle payload integration requirements at the payload user development facilities. The target cost for this simulation device was \$2.0M DDT&E and \$1.5M for the first Unit.

A design analysis of the Horizontal IVE was conducted to the preliminary design level. Orbiter payload accommodations not baselined at the time of this study were developed conceptually in sufficient depth to verify IVE design approach and to support the IVE schedule and cost analyses. The IVE preliminary design analysis was based on a set of requirements (Section 5.0) provided by the NASA representing the STS program, Shuttle Orbiter program, launch site and payload community.

The IVE described herein is a high fidelity replica of the Orbiter payload accommodations providing the capability to verify the form, fit and functional compatibility of the payload to the Orbiter and also support payload development. Configuration drawings were generated showing the design details of the IVE. Subsystem functional block diagrams were developed identifying major elements and the physical and functional interfaces to make up the IVE system. Design trades were

(1) design commonality for Horizontal and Vertical IVE configurations, and (2) Orbiter flight (design) avionics vs a mix of Orbiter design (non-flight qualifiable hardware) and commercial test equipment. A common design approach for the IVE for operation in either a horizontal or vertical position, feasible with a minimal design penalty, was selected for further IVE development.

Maximum use of commercial test hardware with a minimum of Orbiter design, non-flight qualifiable hardware was used in the electrical subsystems rather than flight hardware to (1) provide increased operational flexibility; (2) avoid tieing the IVE hardware to Orbiter flight hardware which would require a change to the IVE every time a design change to the Orbiter hardware occurs, even though the payload interface may not be affected; (3) avoid dependency and availability of IVE hardware on Shuttle Orbiter schedule and priority use of components, and (4) provide least cost.

The IVE potential for other applications in support of the Shuttle to payload integration process was investigated. Areas of investigation in addition to payload interface verification included use as: a design tool, a mnaufacturing aid/production tool, support ground operations procedures development and a training aid for ground and flight crew. Further analysis is required to determine to what degree the IVE may support these applications in a cost effective manner.

A payload integration analysis was conducted to identify potential application of the IVE to support payload development during the DDT&E phase. Payload integration process functional flow block diagrams (a baseline reflecting an objective analysis of payload data provided by the NASA) and two alternates reflecting maximum integration performed prior to arrival at the launch site (Option 1), and maximum integration performed at the launch site (Option 2), were develped for the following five payloads as representative of the broad spectrum of payloads: Solar Maximum Mission, Solar Physics Dedicated Mission, Module with Pallet (Spacelab), Large Space Telescope and Mariner Jupiter Orbiter/IUS. The degree of knowledge of the Orbiter required during the payload integration process was determined and IVE capability to support the integration functions were identified.

The feasibility and cost effectiveness of a non-facilitized (stand alone device requiring no support GSE) payload integration device (IVE) has been established. This IVE device may support not only payload interface verification, payload functional checkout and mission simulation but also may support other applications as discussed above.

The Horizontal IVE concept developed in this study represents a first attempt to define a low-cost standard integration device to support the verification that a payload/cargo is compatible with the Shuttle/Orbiter prior to on-line payload installation into the Orbiter. Further analysis is required to (1) "firm up" STS and payload program requirements, and (2) assess multi-applications/design commonality of integration hardware prior to initiation of the next phase of IVE development.

2.0 INTRODUCTION

This document describes the technical analyses performed during the Shuttle Payload Interface Verification Equipment (IVE) Study conducted by the Space Division of Rockwell International for the NASA. It describes (1) the background and intent of the study, (2) study approach and philosophy covering all facets of Shuttle payload/cargo integration, (3) Shuttle payload integration requirements, (4) preliminary design of the Horizontal IVE, (5) Vertical IVE concept, and (6) IVE program development plans, schedule and cost. The study also includes a payload integration analysis task to identify potential uses of the IVE in addition to payload interface verification.

3.0 BACKGROUND

The objective of the Shuttle payload integration processes is to bring the Shuttle and payload programs together to achieve an acceptable level of mission success with minimum cost and risk to both programs. The Space Shuttle Transportation System operator, and the various payload programs (including the payload carrier developer, and payload developers, the carrier payload integrators, and the carrier payload operators) have to develop an implementation process and the necessary tools to accomplish this objective.

The integration process must consider single and mixed payloads (cargo) for installation in the Shuttle Orbiter Payload bay. This integration process may occur at the launch site, or at other payload or carrier users sites. In the Shuttle Program approach, the integration of payload into the Shuttle system has been limited to the idea of what is necessary to install a payload into the Orbiter payload bay. The Shuttle program assumes that the payload, like any other element of the Shuttle system, has been checked out prior to mating with the Orbiter in order to meet the 160-hour turnaround requirement for the Shuttle system. The time allocation for payload integration during the on-line flow was limited; consequently, the on-line tasks were restricted to the physical mating, continuity check of the electrical and signal interfaces, leak check of the fluid system, and final servicing prior to launch.

If a problem occurs during the integration process, the on-line timeline will be extended or at least placed in jeopardy and the cost per flight (ground operations portion) may increase.

From both the Shuttle Program point of view and the Payload Program point of view, there appears to be a segment for an off-line integration capability in order to avoid extending on-line P/L integration timelines. Prior to the start of this study, this capability was identified as (1) a Shuttle Integration Device (SID) by KSC, (2) a Shuttle base simulator by GSFC, and (3) an Orbiter/Spacelab Simulator by MSFC.

Supporting the needs of these various organizations, NASA/KSC/Goddard/MSFC, and JSC jointly sponsored a study to define a common design low cost simulation device to replace the above identified integration devices. The study was initiated with Rockwell International under CCA 140 to the NAS9-14000 contract. This study was identified as the IVE study - "IVE" standing for "Interface Verification Equipment." NASA and DoD participation in the study is shown in Figure 3-1. Initial requirements were provided by MSFC for the Spacelab program. The study was expanded to include NASA and DoD participation to provide a broader treatment of Shuttle/Payload interface verification. NASA/GSFC/KSC and Aerospace (for DoD) provided their unique requirements.

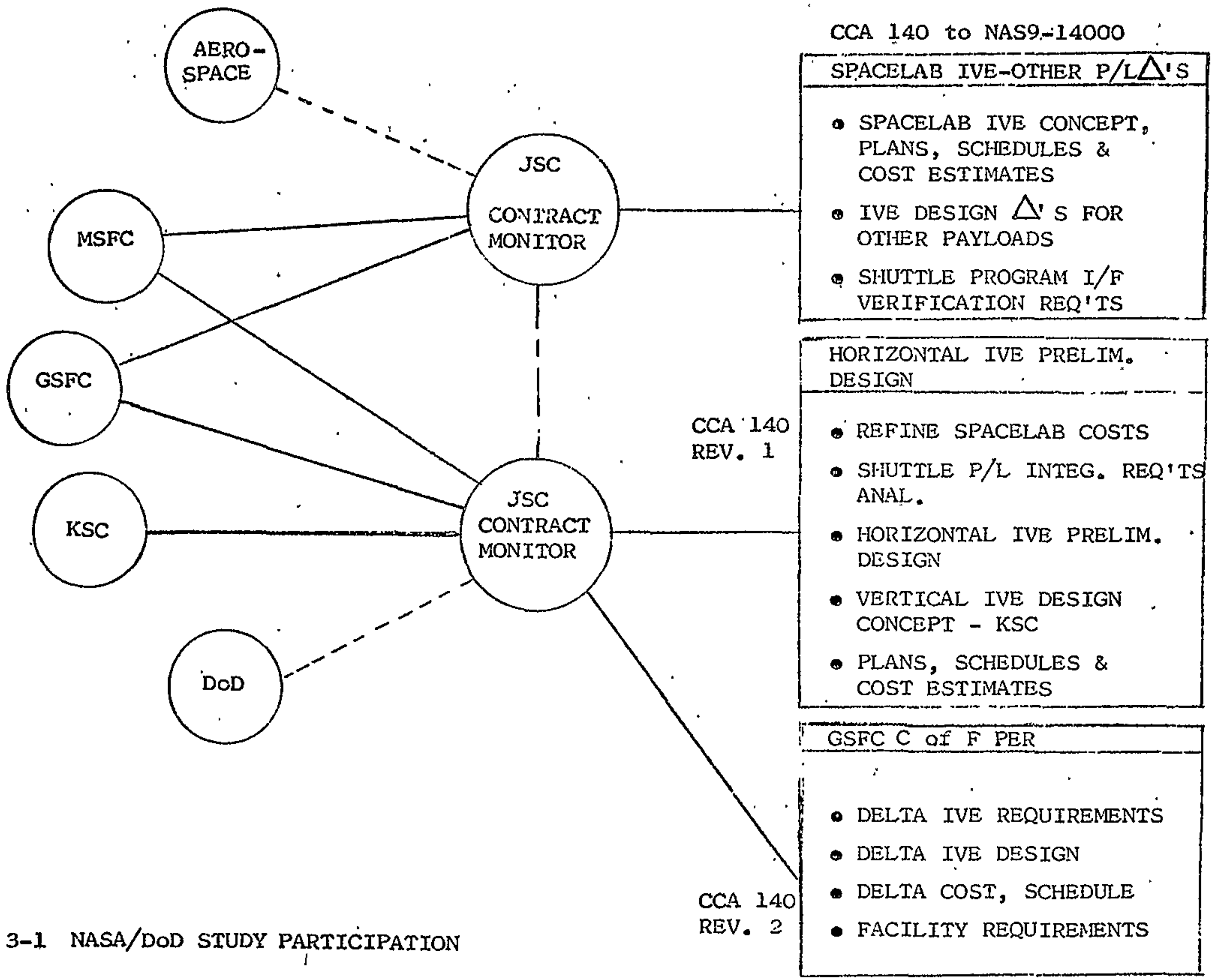

FIGURE 3-1 NASA/DoD STUDY PARTICIPATION

NASA/JSC Shuttle Program Office supported the study to develop payload to Shuttle interface verification requirements (inputs to the "Space Shuttle System Payload Interface Document, Vol. I, "General Approach and Requirements," document No. JSC 07700-14-PIV-01.

The initial study tasks, approach logic and outputs are shown in Figure 3-2. Upon completion of the initial study, MSFC provided additional funding to update and refine the Spacelab IVE design and provide more detailed IVE specification and cost data (Tasks 1 and 2 of the CCA Rev. 1 study as shown in Figure 3-3). GSFC and KSC provided funding to conduct a preliminary design of the Horizontal IVE to reflect the broad spectrum of payloads. In addition GSFC requested an analysis be performed to define Shuttle Payload Integration functional flow block diagrams (reflecting the broad payload spectrum) to identify other potential applications of the IVE. KSC requested a specific task to develop a vertical IVE concept using the Horizontal IVE as a starting point and determine required design deltas.

A separate study (CCA Rev. 2) was funded by GSFC to provide inputs to a Preliminary Engineering Report for C of F (cost of Facility) requirements. Data included design deltas for a single IVE to be used in both a horizontal and vertical position and incorporate capability for IVE to perform data processing to support payload functional checkout and payload mission simulation in addition to I/F verification.

The principal IVE study team members are identified in Table 3.1

TABLE 3.1 IVE STUDY TEAM

NAME	ORGANIZATION	PARTICIPATION
R. T. Everline	JSC/Payloads Coord. Office	Study Manager
C. J. Hall	JSC/WA/Systems Integration	Technical Monitor
C. G. Jackson	JSC/WT/Test Division	Mech/Mfg. Specialist
R. Williams	MSFC/Spacelab Program	Spacelab Requirements
E. J. Popovich	KSC/Shuttle Payload Office	Launch Site Reqt's
R. E. Heuser	GSFC/Test Division	Payload Requirements
Capt. M. Harrison	SAMSO/LVR	DoD Interface
E. H. Richardson	Rockwell International	Study Manager
J. Reid	Rockwell International	Electrical Design
J. C. Hawkins, Jr.	Rockwell International	Structure Design

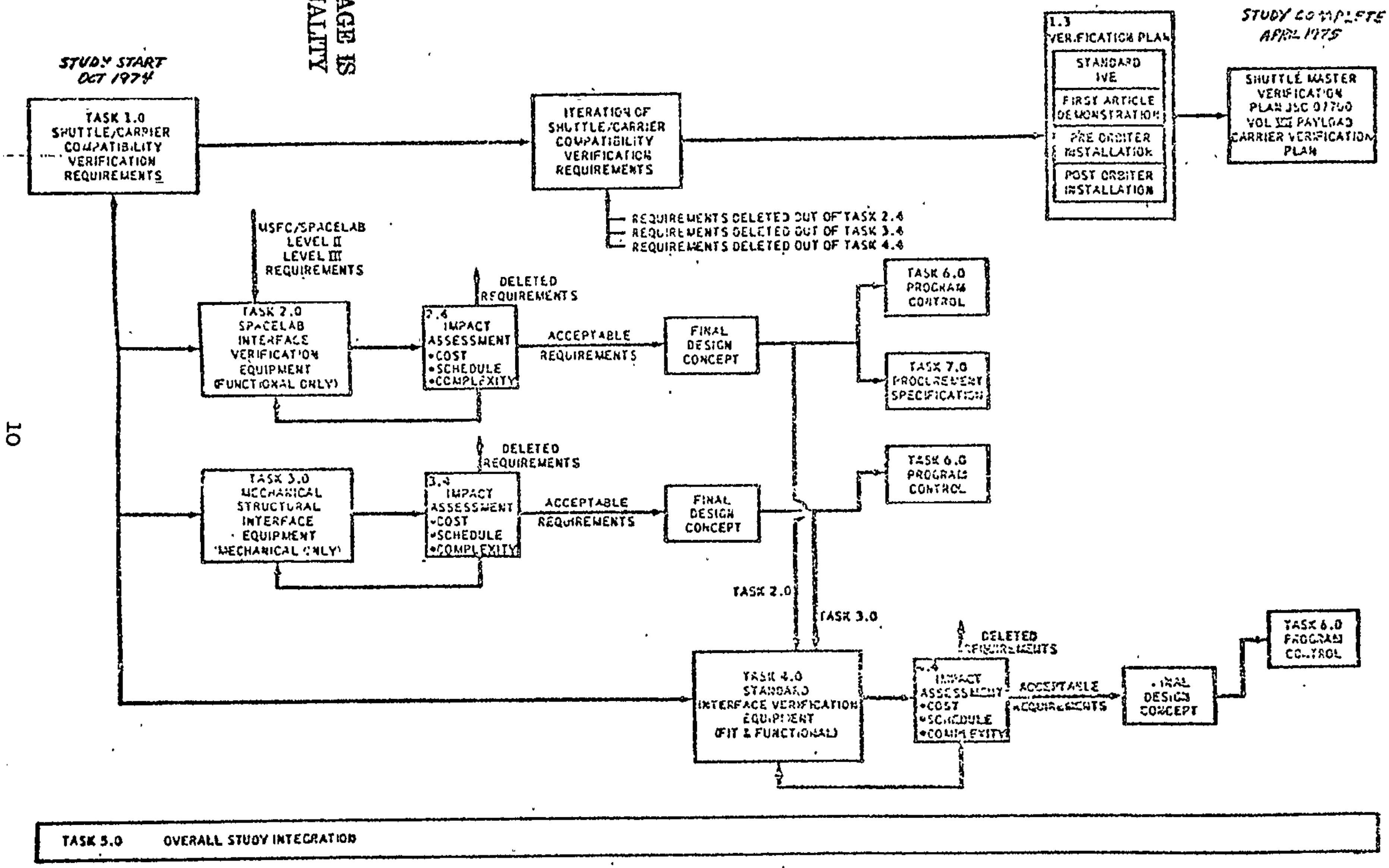

FIGURE 3-2 IVE INITIAL STUDY LOGIC (CCA 140)

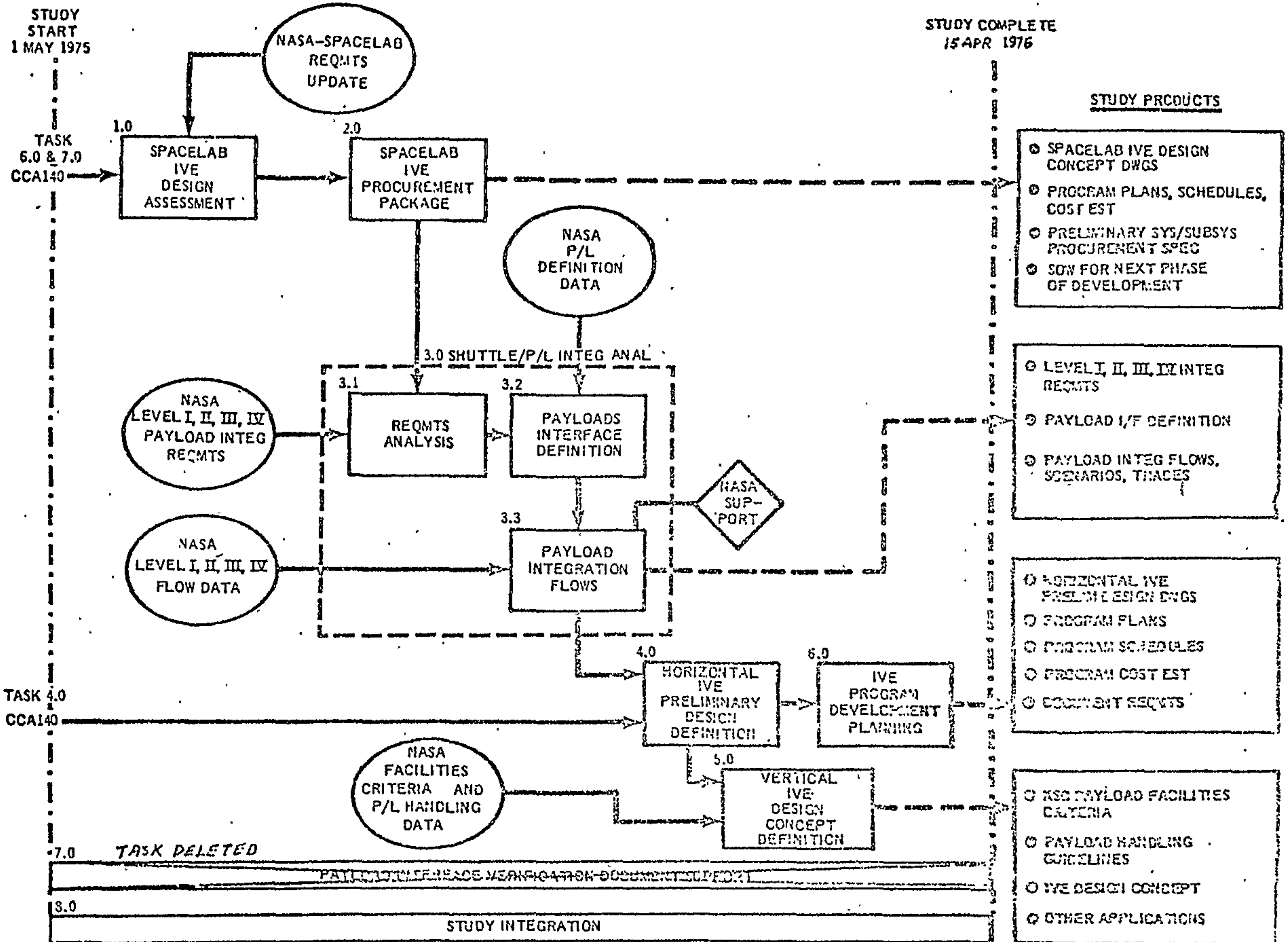

FIGURE 3-3 IVE EXTENDED STUDY LOGIC (CCA 140 REV 1)

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Space Division

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4.0 STUDY SCOPE AND APPROACH

The data presented in the four volumes of this report cover the analyses and results of Tasks 3.0 - Shuttle/Payload Integration Analysis, 4.0 - Horizontal IVE Preliminary Design Definition, 5.0 - Vertical IVE Design Concept Definition and 6.0 - IVE Program Development Planning as shown in Figure 3-3. Results of Tasks 1.0 - Spacelab IVE Design Assessment and 2.0 - Spacelab IVE Procurement Package were documented in a data package and submitted to MSFC for review and approval in July, 1975. Copies were also distributed to all study team members.

The data generated in Task 2.0 was used as a baseline from which the Horizontal IVE preliminary design effort was initiated. Task 5.0 Vertical IVE design concept was conducted concurrent with Task 4.0. The common primary structural design requirement necessitated an integral design approach rather than "beefing up" the Horizontal IVE structure with "add on" structure in order to achieve the most cost effective design approach.

Task 3.0 was an independent analysis of Shuttle/Payload integration processes. Data provided by NASA was analyzed and payload integration functional flow block diagrams (FFBD's) were generated for five payload configurations representative of the broad payload operation. The degree of Shuttle knowledge required to support the integration activities defined in the FFBD's was determined and potential application of the IVE to support payload integration was identified. The results of Task 3.0 provide the basis for NASA to conduct payload integration trade studies. The Horizontal IVE design Task 4.0 was not impacted by the results of Task 3.0; however, many of the requirements imposed on the IVE by the payload users was derived from the same payload data sources.

In Task 6.0 program plans were developed compatible with the Horizontal IVE preliminary design level (Phase B study) to provide an adequate planning base for initiation of the next development phase of the IVE. Project plans described include: management, configuration control, quality assurance, make or buy, subcontractor management, acceptance test and logistics management. As part of Task 6.0 an IVE project master development schedule was generated. A work breakdown structure (WBS) and description of Tasks (WBS dictionary) was generated.

The design data from Task 4.0, development planning data, schedule, and WBS were used to support the IVE cost analysis. The cost analyses was based on inputs from the design and manufacturing elements of Space Division, vendor quotes and off-the-shelf hardware (commercial) prices adjusted to reflect January 1976 prices.

5.0 REQUIREMENTS AND CONSTRAINTS

5.1 IVE REQUIREMENTS

The functional requirements impacting the design and performance of the IVE are grouped into three categories as follows:

1. Payload Requirements - representative user requirements as defined by NASA/MSFC/GSFC and KSC and DoD.

2. Shuttle Program (JSC) Requirements - requirements imposed on the user to verify payload compatibility with the Orbiter.

3. Space Transportation System Requirements - requirements imposed on the Shuttle Program and the payload users to assure cargo compatibility with the Orbiter.

5.1.1 Payload Requirements

The payload requirements governing the design of the IVE are described in detail in the following documents:

- Spacelab Specification, Performance, Design and Verification Requirements for the Shuttle Interface Verification Equipment, NASA/MSFC 45A00000, March 18, 1975.

- GSFC Requirements for the Interface Verification Equipment (IVE) Study, Letter dated November 19, 1974.

- KSC Hardware Requirements for Interface Verification Equipment, KSC Letter SP-PAY-9-75, January 23, 1975.

- Interface Verification Equipment (IVE) Study Extension, Task 5.0 Vertical IVE Design Definition, KSC Letter and dated August 15, 1975.

- Interface Verification Equipment (IVE) - Summary Information, Aerospace Letter 74-2610.5-H146, dated 24 October 1974.

5.1.2 Shuttle Program Requirements

The Shuttle Program (NASA/JSC) requirements imposed on the IVE include:

1. Simulate all Orbiter payload accommodations as defined in the Space Shuttle Payload Accommodations Document, JSC 07700, Vol. XIV.

5.1.2 (Cont'd)

2. Orbiter payload interfaces requiring verification and methods of accomplishment are as defined in the Space Shuttle System Payload Interface Verification Document, Vol. I, General Approach and Requirements, Document No. JSC 07700-14-PIV-01.

5.1.3 Space Transportation System (STS) Requirements

The STS required that the IVE be capable of supporting the integration and verification of the multiple payload elements (mixed payloads) which institute Orbiter cargo.

5.1.4 IVE General Requirements Summary

The major general requirements driving the design of the Horizontal IVE are summarized in Table 5-1. The requirements were evolved using the initial Spacelab requirements as a baseline. Also included in Table 5-1 is the rationale for the requirement.

5.2 IVE DESIGN CONSTRAINTS

The following constraints were imposed by NASA impacting the IVE design:

1. Interface areas excluded from IVE design concept due to cost and/or other existing or planned Shuttle developments.

   a. Payload Flight Software Verification

      This capability was excluded because software verification would require IVE to use Flight GPC which is a major cost item. The IVE controller/control processing unit (C/CPU) provides capability to support development of the payload flight software by sizing checks and timing operations.

   b. EMI/EMC Verification (Orbiter/Payload)

      This capability was excluded because it would drive cost and design complexity of IVE. IVE will support testing of the payloads conducted interference independent of Orbiter. If EMI/EMC verification testing is required, it may be more economical to delay testing until payload is installed in the Flight Orbiter at the launch site.

TABLE 5-1. GENERAL IVE REQUIREMENTS (CONT'D)

REQUIREMENT	RATIONALE/COMMENT
10. IVE will not degrade a standard 100K clean environment.	10. Intent was to define a minimum requirement for the IVE design. Individual payloads having a more stringent cleanliness requirement would have to upgrade the equipment at their cost.
11. Simulate Orbiter Standard interfaces to payloads in form, fit, and function.	11. The intent of this requirement was to constrain the capability of the IVE to only the Standard Orbiter interfaces as reflected in JSC 07700, Vol. XIV.
12. High Fidelity at the interface only	12. The intent of this requirement was to minimize cost of the IVE. For example this requirement allowed the design to utilize a simple structure in the design of the structural IVE.
13. Provide interface for payload GSE.	13. This capability would allow a rational expansion of the IVE to support lower levels of integration without augmentation of the system.
14. Provide interface for software verification in "bent pipe" mode.	14. Software verification was a capability specifically excluded from the IVE design; however, it was recognized that providing an interface with existing systems such as SAIL or LPS could facilitate payload integration.
15. Data Processing.	15. This requirement was added late in the study as an added capability. It was clear from the review in July 1975 that several potential users of the IVE would augment their system with this capability in the field.

TABLE 5-1. GENERAL IVE REQUIREMENTS (CONT'D)

REQUIREMENTS	RATIONALE/COMMENT
	5. b. Requirement also recognized the potential of the IVE to meet other payload needs as the total STS matured. Example: As a design tool, manufacturing aid, training aid, etc.
6. Easily transportable by commercial transportation.	6. a. Intent was to assure that should the IVE be built at a contractor's facility in one geographical location it could be moved to the users' facility in another geographical location without incurring the cost of developing a special transport device. b. It appears that more than one set of IVE would be required to support the operational era of the Shuttle and in all probability at different geographical areas.
7. Easily assembled and certified for use.	7. Intent was to facilitate field assembly of the IVE and self check capability for certification prior to each use.
8. Configuration Management simplified and current.	8. a. Basic intent was to make the Shuttle Program and the Orbiter Contractor accountable for the IVE Configuration management and control. b. Simply stated, this was the payloads insurance policy.
9. Logistic Support.	9. Primarily, a Spacelab Program requirement to insure adequate support to the IVE located at ERNO; however, all payload users involved in study require an adequate Logistics support system for their IVE.

TABLE 5-1. GENERAL IVE REQUIREMENTS (CONT'D)

REQUIREMENT	RATIONALE/COMMENT
10. IVE will not degrade a standard 100K clean environment.	10. Intent was to define a minimum requirement for the IVE design. Individual payloads having a more stringent cleanliness requirement would have to upgrade the equipment at their cost.
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15. Data Processing.	15. This requirement was added late in the study as an added capability. It was clear from the review in July 1975 that several potential users of the IVE would augment their system with this capability in the field.

TABLE 5-1. GENERAL IVE REQUIREMENTS (CONT'D)

REQUIREMENT	RATIONALE/COMMENT
16. IVE impose no design requirements on the payload in addition to those imposed by Orbiter for payload compatibility verification.	16. Preclude the IVE from impacting the design of the payload except with respect to Orbiter interfaces and support.
17. Automated (with manual) operational mode	17. All payload users involved in the study required automated checkout.
18. Common structure design for horizontal and vertical IVE configurations.	18. Common design desired if practical from an economical viewpoint.

5.2 (Cont'd)

c. Dynamic loads simulation (Vibro-Acoustic) to support either payload acceptance or DDT&E testing. This capability was excluded since it would drive the cost and design complexity of IVE. Use of the math models developed in the Shuttle program would be a more economical solution to this requirement.

d. Payload Bay thermal environment simulation to support either payload acceptance or DDT&E testing.

This capability was excluded since it would drive the cost and design complexity of IVE. Use of the math model developed in the Shuttle programs would be a more economical solution to this requirement. IVE provides payload heat exchanger for active thermal control of payloads.

e. Payload Bay active purge.

This capability was excluded since it would drive the cost and design complexity of IVE. While the design does not preclude augmentation to include a purge capability, it would be costly. Would involve major facility impact.

f. Remote Manipulator System

Capability excluded due to high cost (IVE RMS and facility) to perform viable simulation tests.

g. RF Payload Interface

No requirement was identified by study team. Capability exists to augment the IVE to include the RF interface.

The basic design of the IVE does not preclude augmentation to include the above design limitations with associated increase in cost.

2. Other constraints placed on the study to provide IVE operational flexibility and design commonality include:

   a. IVE support maximum payload of 65,000 pounds with safety factor of 4.

   b. IVE primary structure sized for worst case loading for entire payload bay (common size of structural members).

5.2 (Cont'd)

e. Workstands are excluded from the IVE study. IVE shall not preclude using Shuttle/Orbiter workstands (provide clean design lines for IVE).

6.0 HORIZONTAL IVE PRELIMINARY DESIGN

6.1 GENERAL DESCRIPTION

The basic IVE concept consists of two classes of equipment referred to as (1) standard IVE and (2) optional equipment. The standard IVE consists of the basic structure, operators console and those interface elements which are essentially used by the majority of payloads. Two exceptions are the inclusion of the provision for the preflight (T-4) umbilical panel and the X_o1307 bulkhead structure. The major elements of the standard IVE are shown in Figure 6-1. Optional equipment includes those payload interface elements that are unique to a specific payload or class of payloads as identified in Figure 6-2.

The primary criteria impacting the IVE design concept is given in Table 7.1. A key feature of the IVE design is its modularity which permits use of a portion of the IVE (single mid-body section, operators console, etc.) resulting in the inherent cost advantages associated with tailoring the configuration for specific user needs.

As defined in this study the IVE is a set of dimensionally accurate physical and functional hardware representative of the Orbiter payload accommodations. It provides the capability to verify Orbiter/Payload I/F compatibility, support payload functional and performance checkout including mission simulation, and support development and verification of ground operations including crew training, procedures and payload handling GSE. Major emphasis was placed on the use of either off-the-shelf hardware or previously developed Orbiter related hardware to minimize engineering development and procurement costs.

The following sections describe the Horizontal IVE, what it does, what it consists of and how it operates.

6.1.1 Horizontal IVE Structure and Mechanisms Subsystems

The standard IVE structure consists of the primary structure (all major load carrying members in the mid-body supporting the payload), and the secondary structure (aft flight deck support stand, the X_o576 and X_o1307 bulkheads, and brackets necessary to support the payload interface elements). The standard IVE mechanisms include the following payload interface elements: payload support attach fittings (longeron and keel). primary power interface, payload wire trays (right and left side), preflight umbilical (T-4) panel provision, RMS and door actuator critical interference envelopes, and adjustable floor jacks (leveling of IVE system assembly).

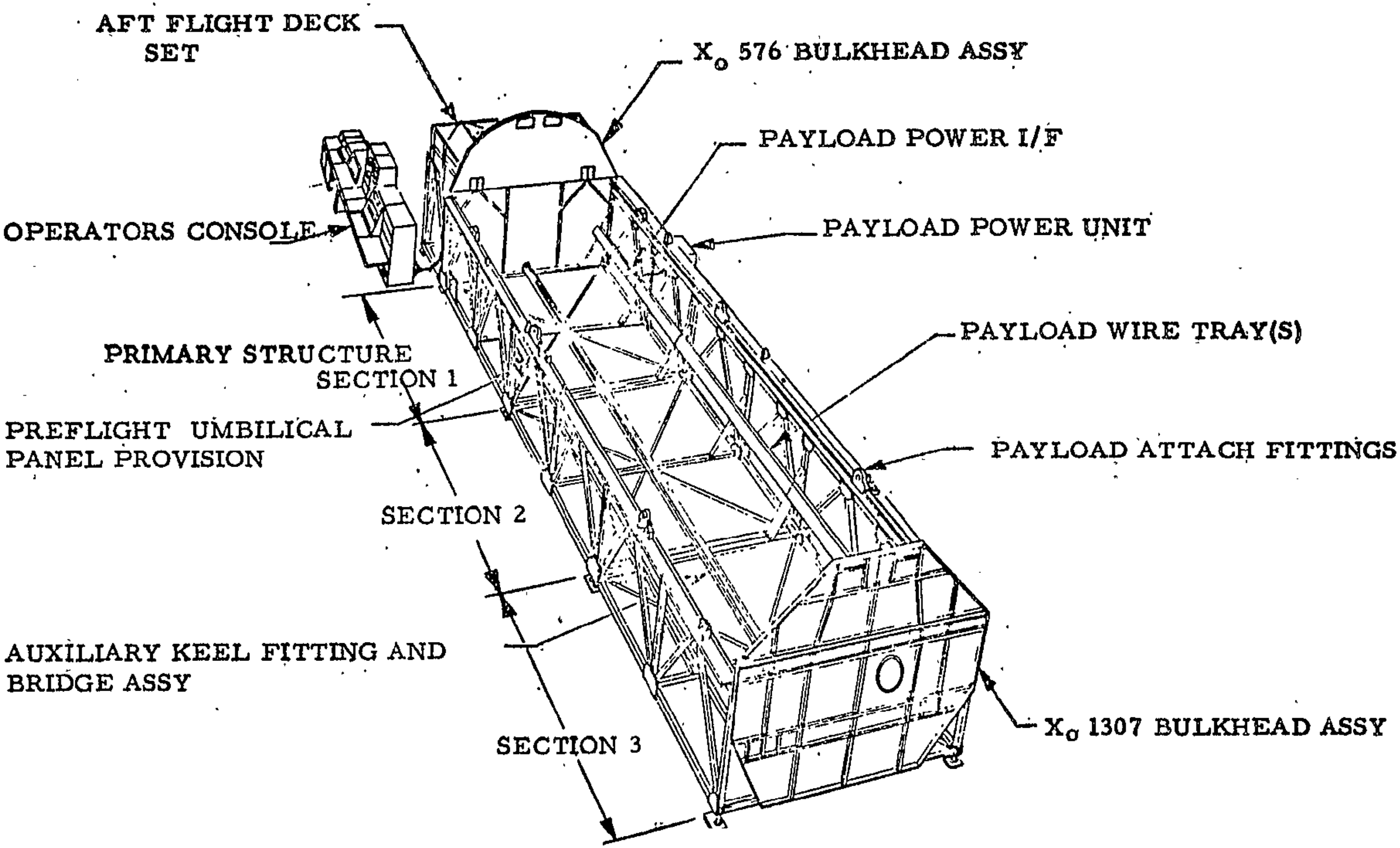

FIGURE 6-1 STANDARD HORIZONTAL IVE CONCEPT

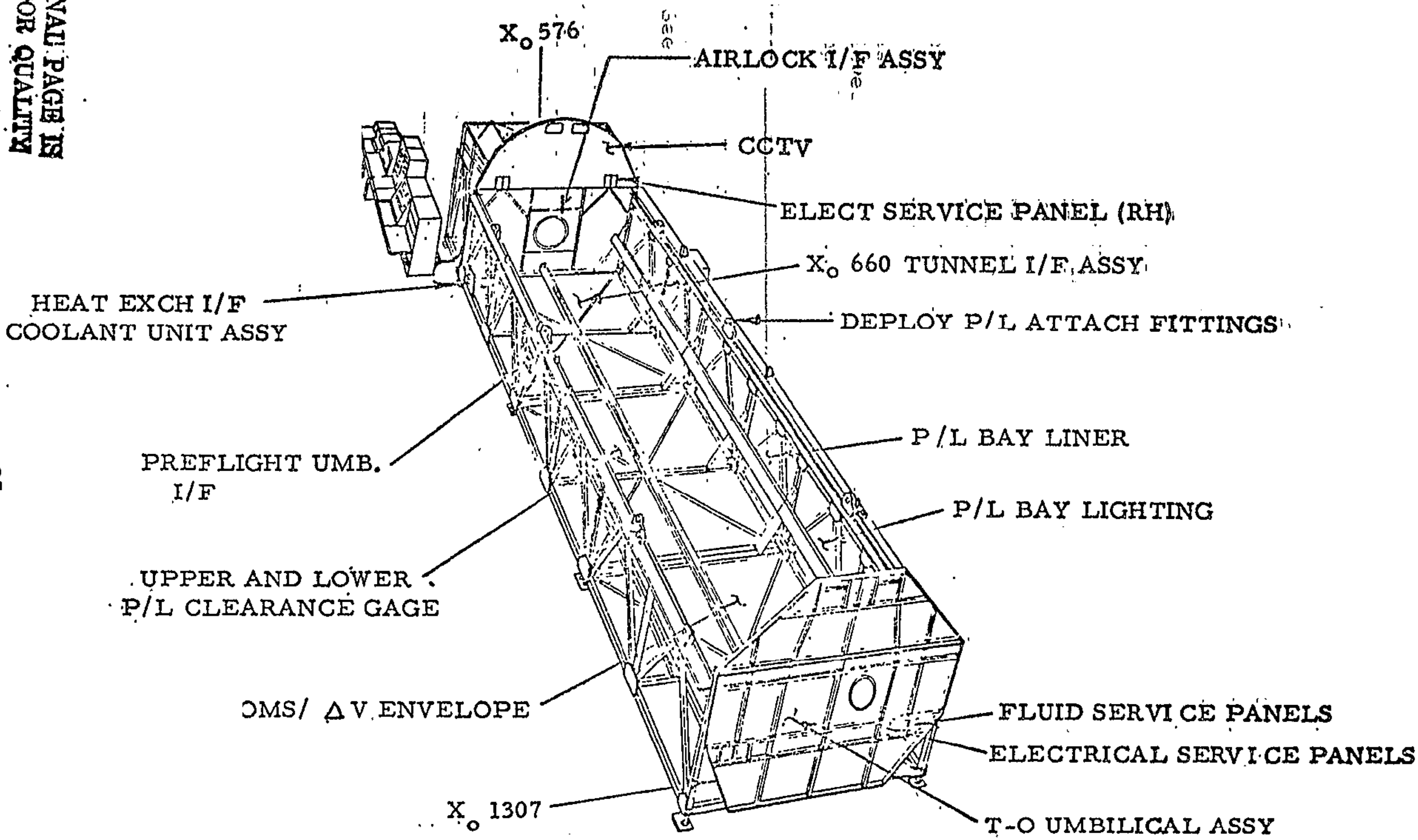

FIGURE 6-2 IVE OPTIONAL EQUIPMENT

The primary structure utilizes design commonality to maximum advantage resulting in over all cost savings. Three mid-body sections identical in structural member design, make up the IVE mid-body (Figure 6-1). The primary structure was sized to meet the requirements for a maximum 65,000 pound payload using a common structure design for both horizontal and vertical IVE configurations.

A major concern impacting the IVE structural design is the operational support required to assemble, checkout and verify that the IVE is a valid configuration at the user site. IVE structural reassembly verification is acheived through the use of engineering tooling aids including optics, tool alignment pins, and alignment markers integral with the structure, and a master alignment tool to verify that critical payload interfaces are within allowable design tolerances. The IVE structure and mechanisms were designed for minimum maintenance over long operational times (10-20 years). Periodic structural alignment verification is achieved by optically checking the alignment of the bridge rails and using the master alignment tool to verify the payload interface elements.

6.1.2 Horizontal IVE Electrical Subsystem

The standard IVE electrical subsystem includes the operators console, the aft flight deck set, the DC power set, the cable set and software (See Figure 6-3). Key design features include maximum use of commercial test equipment, modular design, "stand alone" (independent) operation (requires no facility support GSE), payload accessibility to payload GSE, IVE accepts control by and delivers data to the payload user site Data Processing Facility, and automated (with manual mode) operation.

Operational capabilities include (1) Orbiter/Payload I/F verification (Pin/connector matching, resistance continuity and isolation checking), (2) Payload functional testing (3) verify Orbiter/payload performance and (4) simulate mission/on-orbit timelines and sequencing.

The electrical system is designed to stimulate the payload with digital commands, over the flight range of values, and receive responses from the payload subsystem. Design incorporates safeguards for preventing out-of-limit signals from being imposed on payload input circuits. Measurement instruments are provided to measure and record all signal characteristics. Data processing capability is provided with output formats compatible with the Orbiter communication and data handling system.

A DC power unit for the payload +28 vdc buses simulating Orbiter fuel cell performance in the 0 to one Hz range is provided.

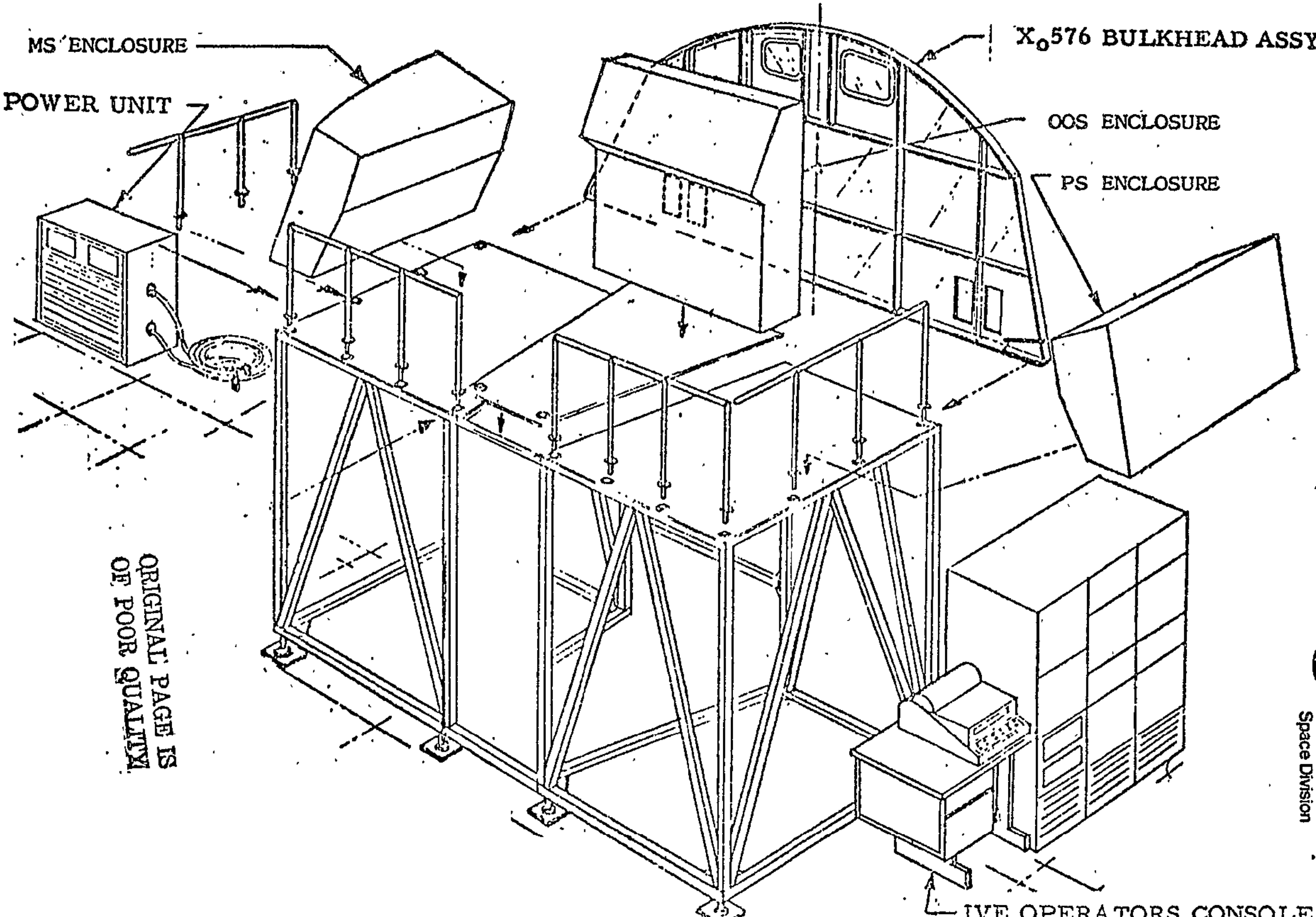

FIGURE 6-3 STANDARD IVE ELECTRICAL SUBSYSTEMS AND AFT FLIGHT DECK CONFIGURATION

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Rockwell International
Space Division

Mechanization of the electrical system (Figure 6-4) is provided by a modular, analog and digital interface verification test system under supervision of a controller/central processor unit. Flexibility of operation is provided by an asynchronous data bus interfacing with commercial proven "off-the-shelf" test equipment and Space Division designed hardware.

Payload Integration functions not incorporated in the IVE design include: EMI/EMC testing, off-limit testing, RF checkout (payload interrogator with detached payload interface) and software validation.

6.1.2.1 Operators Console

The operators console simulates the payload related functions of the Orbiter Communication and Data Handling (C and DH) system and the Flight Computer Operating System (FCOS). Mechanization of the operator console is based on a modular, analog and digital interface verification test system under supervision of a controller/central processor unit C/CPU).

Flexibility of operation is provided by an asynchrounous data bus interfacing with a mix of "off-the-shelf" test equipment and Rockwell International-Space Division designed components. Key factors influencing the design of the electrical subsystem were cost, performance, operational requirements, hardware modularity and software flexibility to accommodate a changing spectrum of data formats.

6.1.2.2 Aft Flight Deck Set (AFDS)

The Aft Flight Deck Set simulates the Orbiter mission station (MS), on-orbit station (OOS), and payload station (PS) including all payload related control and display equipment. The AFDS consists of the $X_0$576 payload service panels,,MS, PS, OOS electronic enclosures, payload related control and display equipment, patch panels and cabling.

6.1.2.3 DC Power Set

The DC power set provides nominal 28 vdc power at 400 amps with variable voltage capability simulating the Orbiter payload fuel cell power interface. The DC power set consists of a commercial DC power supply, power switching assembly and distribution module.

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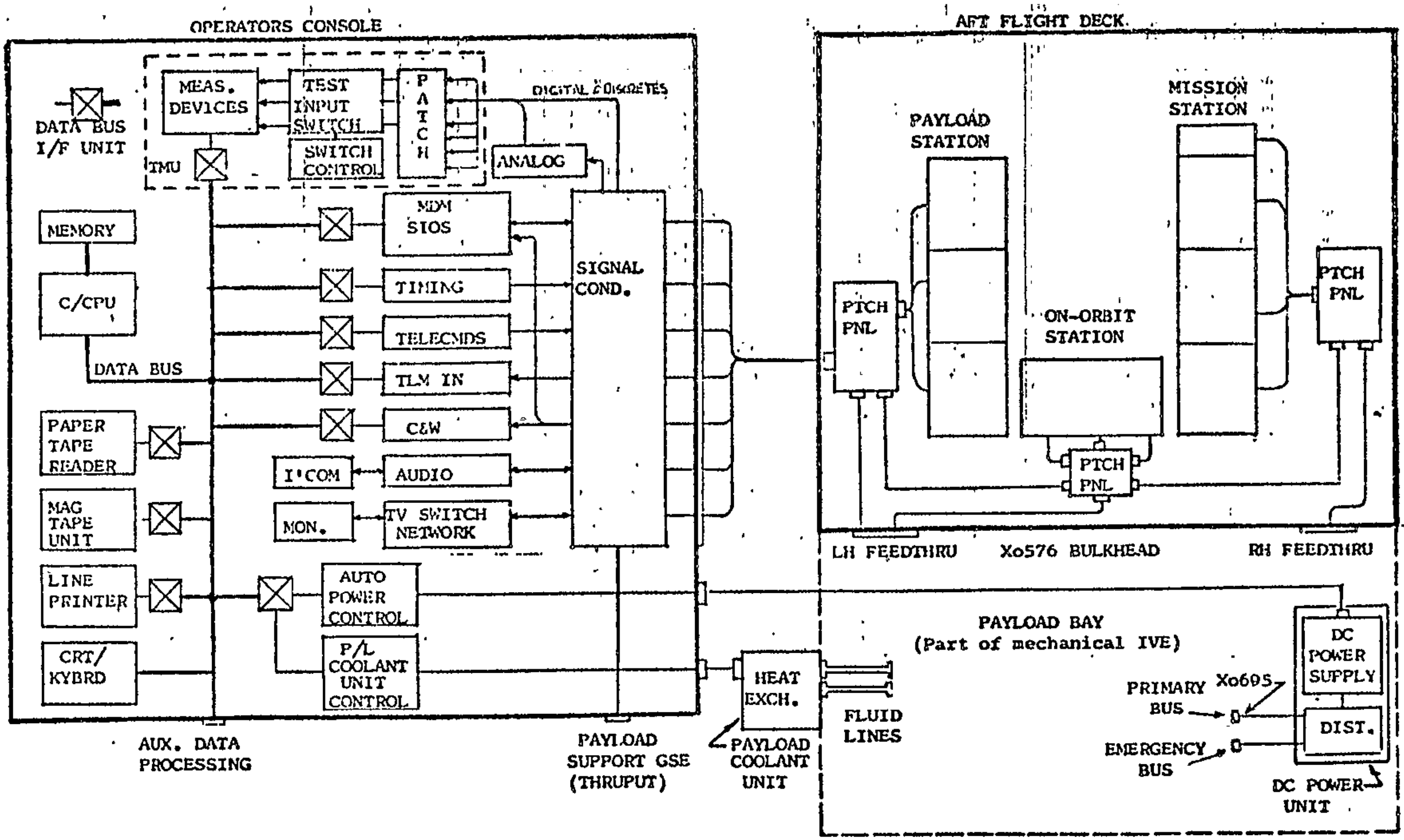


FIGURE 6-4 IVE ELECTRICAL SUBSYSTEMS FUNCTIONAL BLOCK DIAGRAM

6.1.2.4 IVE Software

The standard IVE electrical subsystems include software and programming aids. The System Support Software provides control of all IVE peripherals, special purpose interface handlers (formatters, decoders, etc). The Test Application Software consists of a library of subroutines for performing specific payload-subsystem functions (software building blocks to be integrated into the System Test Program software by the user).

6.1.3 Horizontal IVE Fluid Subsystems

The IVE fluid subsystems, categorized as optional equipment, include (1) the payload heat exchanger and related controls, displays, interface panel, fluid lines and purge and test, (2) X_o1307 fluid interfaces (3) propellant dump line interfaces, (4) ground and flight RTG coolant interfaces and (5) a pressure leak detection unit.

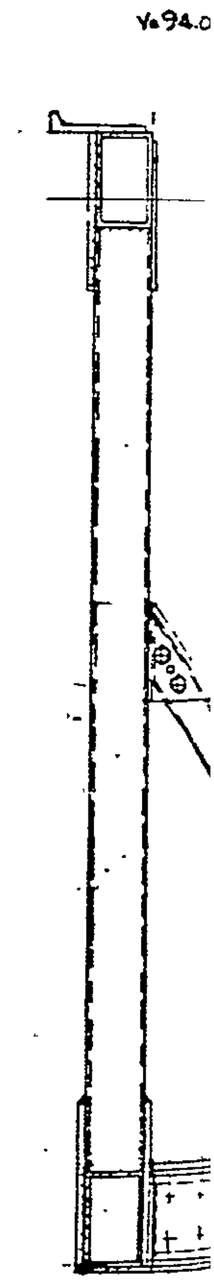
6.2 HORIZONTAL IVE STRUCTURE AND MECHANISM SUBSYSTEMS

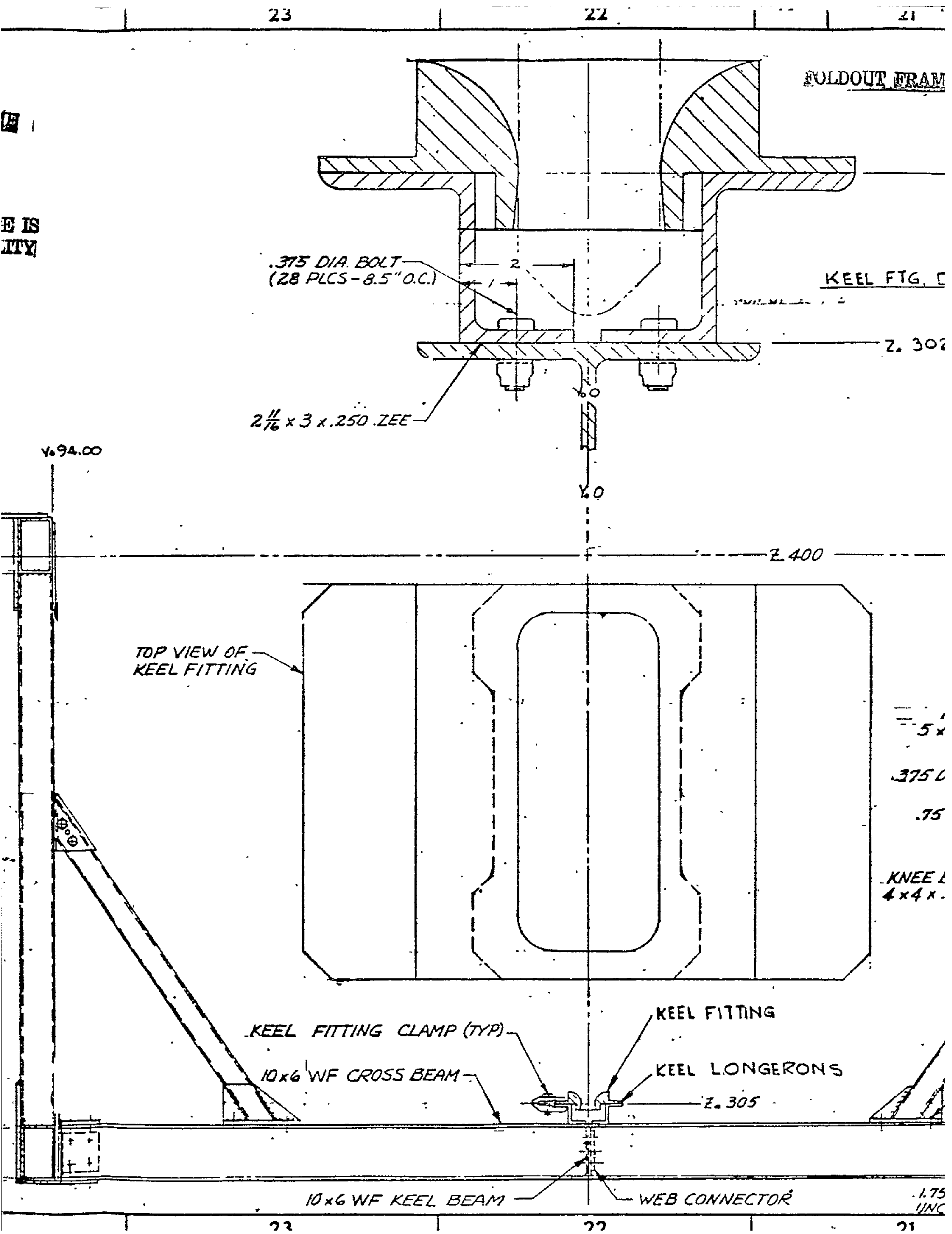
The horizontal standard IVE Structure and Mechanism (S&M) subsystems well designed to provide a high fidelity replica of the Orbiter/payload interfaces to accomplish form and fit check for payloads, and to support payloads up to 65,000 pounds in both the horizontal and vertical configuration. The standard IVE structure consists of (1) primary structure (2) secondary structure and (3) selected payload interface elements common to all of the payloads as identified in Figure 6-1. S and M subsystem optional equipment augmenting the Standard IVE is identified in Figure 6-2.

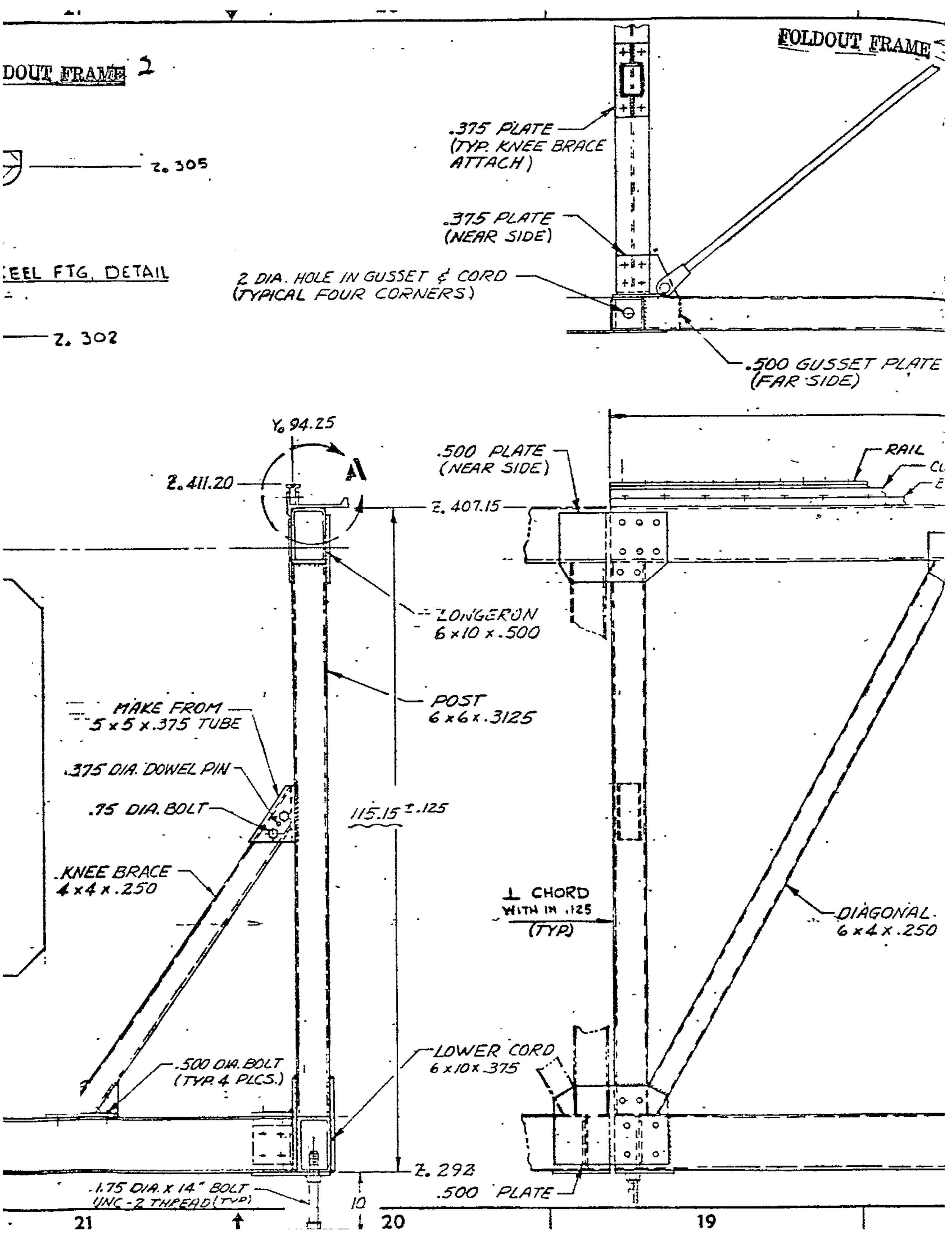
The following sections describe the horizontal IVE structure and mechanisms. Additional information is contained in Appendices A through B of Volume II of this report and Vol. III Horizontal IVE Specification Data.

6.2.1 Primary Structure

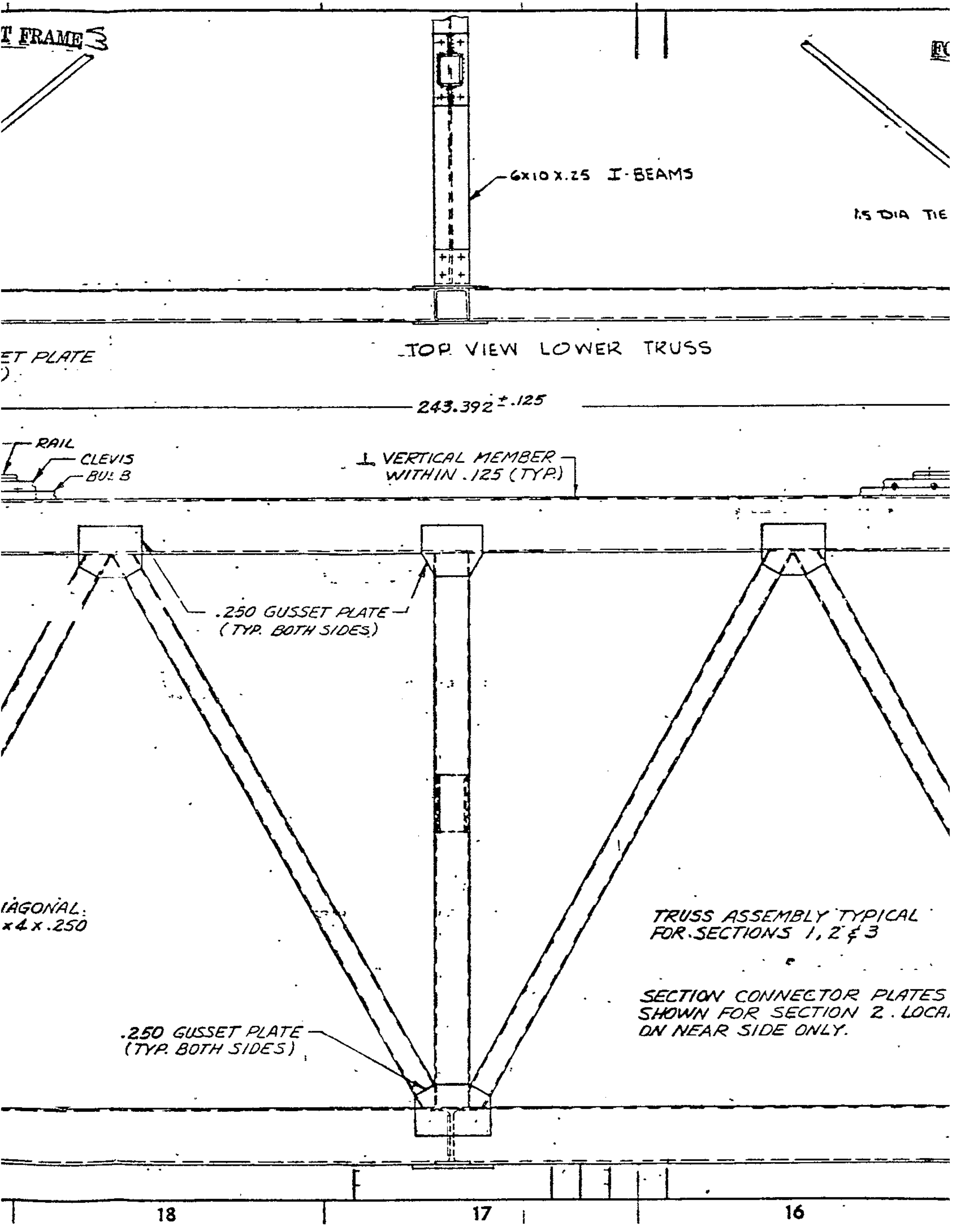
The primary structure consists of all load carrying members required to support the payload and are identified as Sections 1, 2 and 3 in Figure 6-5 showing design details. Each 20 foot section was designed to carry the maximum payload weight of 65,000 pounds in the horizontal and vertical configuration at any X_o location in order to simplify the structural design. Two subdivided Warren Truss assemblies interconnected with cross beams and stabilized with knee braces and diagonal tie rods make up a mid-body section. All three sections are identical prior to incorporation of secondary structure and payload interfaces. The modified


Y=94.0

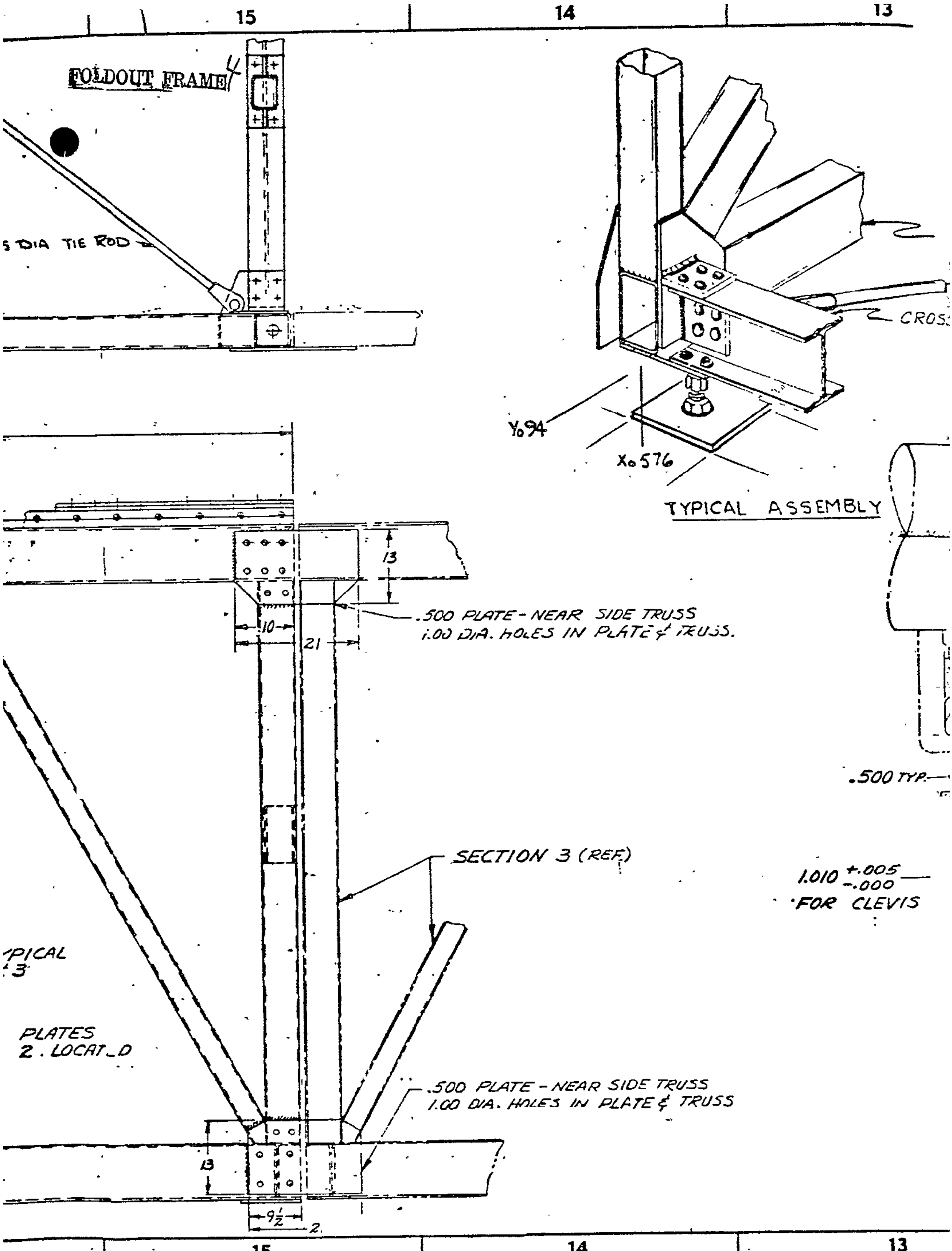

23
22
21
.375 DIA. BOLT
(28 PLCS - 8.5" O.C.)
2
1
2 11/16 x 3 x .250 ZEE
Y.0
Y.94.00
Z.400
TOP VIEW OF
KEEL FITTING
KEEL FITTING CLAMP (TYP)
10x6 WF CROSS BEAM
KEEL FITTING
KEEL LONGERONS
Z.305
10x6 WF KEEL BEAM
WEB CONNECTOR
23
22
21



FOLDOUT FRAME 2
FOLDOUT FRAME
Z. 305
EEL FTG. DETAIL
Z. 302
.375 PLATE (TYP. KNEE BRACE ATTACH)
.375 PLATE (NEAR SIDE)
2 DIA. HOLE IN GUSSET & CORD (TYPICAL FOUR CORNERS)
.500 GUSSET PLATE (FAR SIDE)
Y. 94.25
Z. 411.20
A
Z. 407.15
.500 PLATE (NEAR SIDE)
RAIL
LONGERON 6 x 10 x .500
POST 6 x 6 x .3125
MAKE FROM 5 x 5 x .375 TUBE
.375 DIA. DOWEL PIN
.75 DIA. BOLT
115.15 ±.125
KNEE BRACE 4 x 4 x .250
⊥ CHORD WITH IN .125 (TYP.)
DIAGONAL 6 x 4 x .250
.500 DIA. BOLT (TYP. 4 PLCS.)
LOWER CORD 6 x 10 x .375
Z. 292
1.75 DIA. X 14" BOLT UNC-2 THREAD (TYP)
10
.500 PLATE
21
20
19

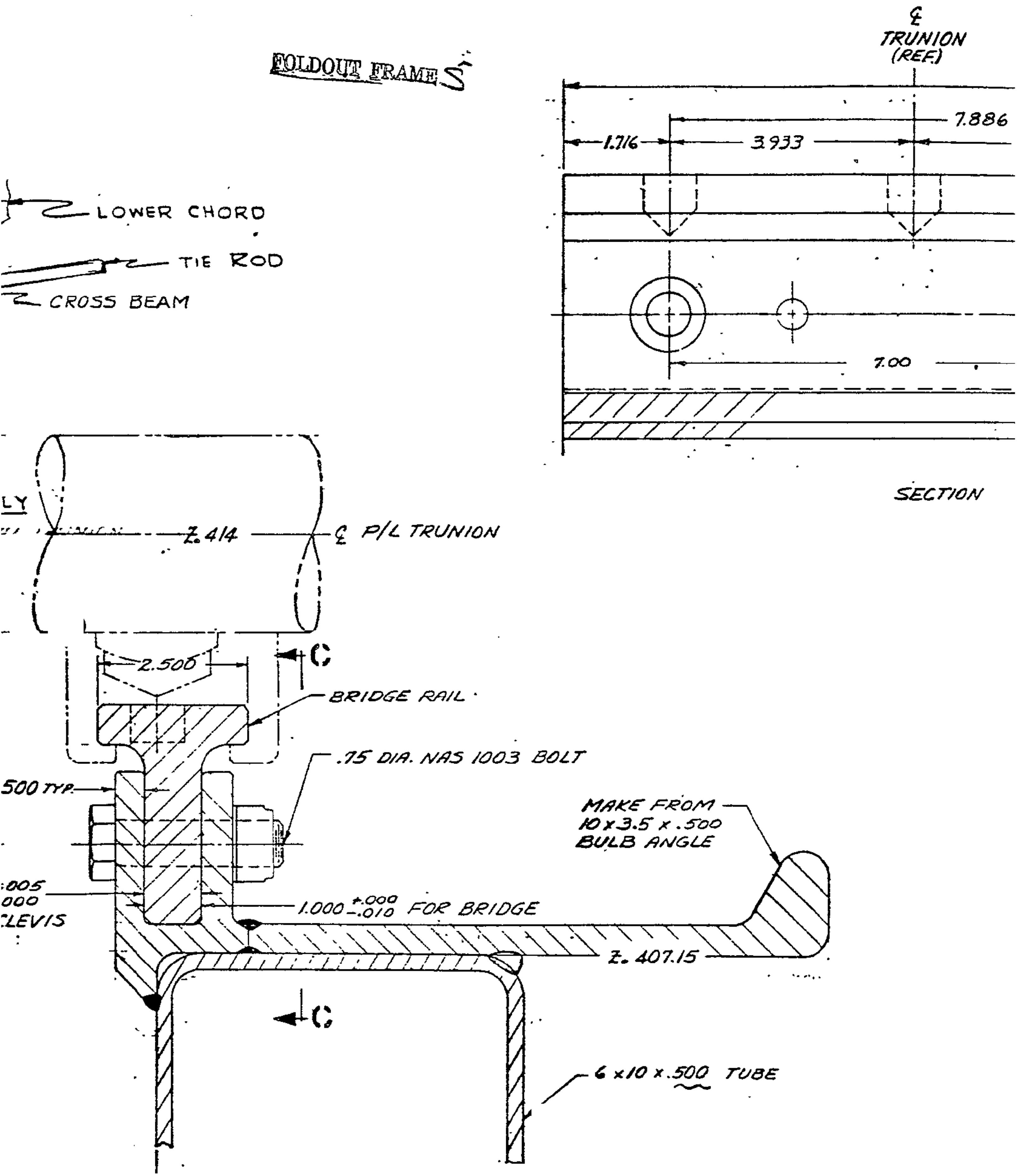


T FRAME 3
6x10 x.25 I-BEAMS
1.5 DIA TIE
TOP VIEW LOWER TRUSS
ET PLATE
243.392 ±.125
RAIL
CLEVIS
BU: B
⊥ VERTICAL MEMBER WITHIN .125 (TYP.)
.250 GUSSET PLATE (TYP. BOTH SIDES)
IAGONAL
x4 x .250
TRUSS ASSEMBLY TYPICAL FOR SECTIONS 1, 2 & 3
SECTION CONNECTOR PLATES SHOWN FOR SECTION 2. LOCA
ON NEAR SIDE ONLY.
.250 GUSSET PLATE (TYP. BOTH SIDES)
18
17
16



15
14
13
FOLDOUT FRAME 4
5 DIA TIE ROD
CROS
Y₀94
X₀576
TYPICAL ASSEMBLY
13
.500 PLATE - NEAR SIDE TRUSS
1.00 DIA. HOLES IN PLATE & TRUSS.
10
21
.500 TYP.
SECTION 3 (REF)
1.010 +.005 -.000
FOR CLEVIS
PICAL
3
PLATES
2. LOCAT_D
.500 PLATE - NEAR SIDE TRUSS
1.00 DIA. HOLES IN PLATE & TRUSS
13
9 1/2
2.
15
14
13

FOLDOUT FRAME 5

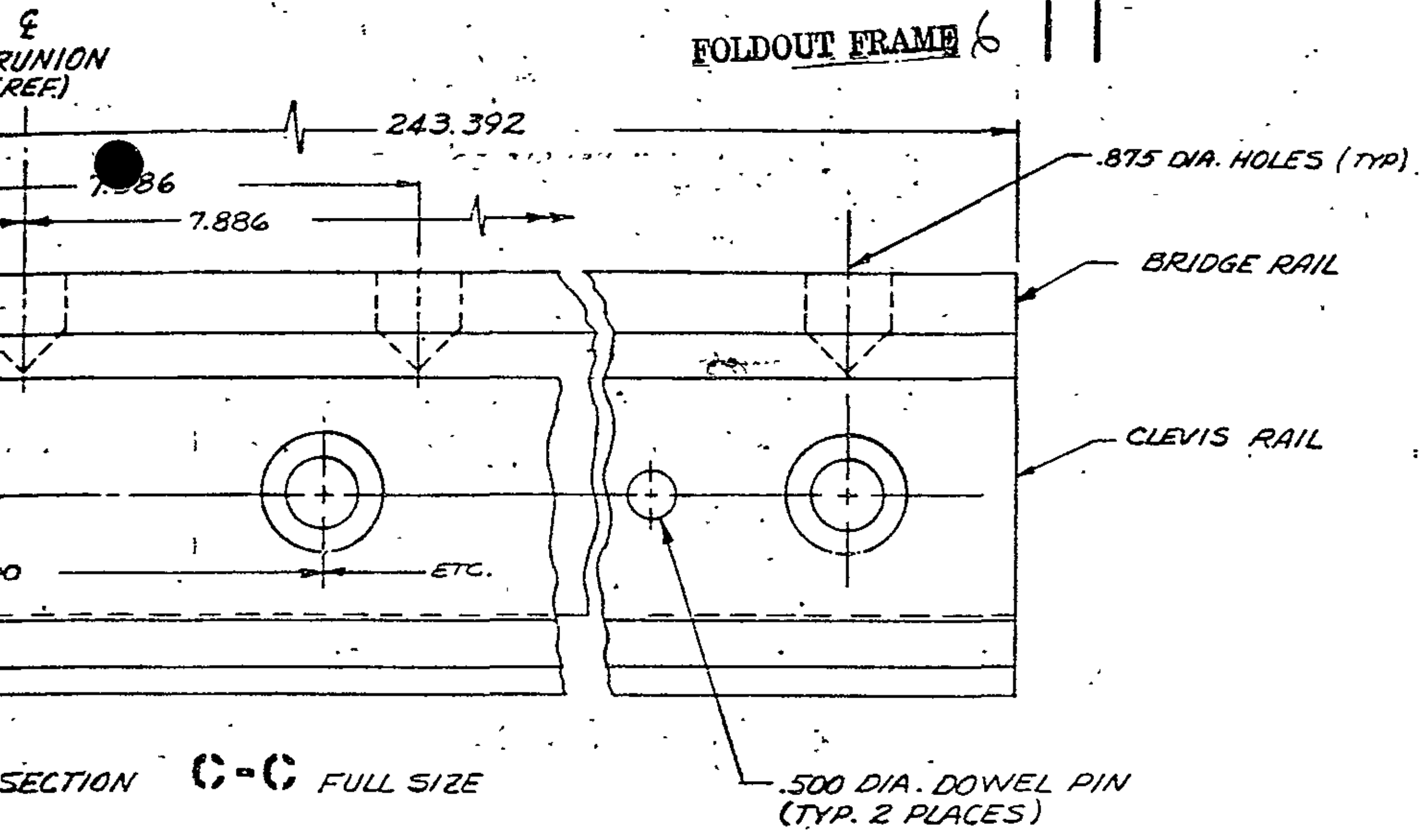


VIEW A FULL SIZE

10 | 9 | 8

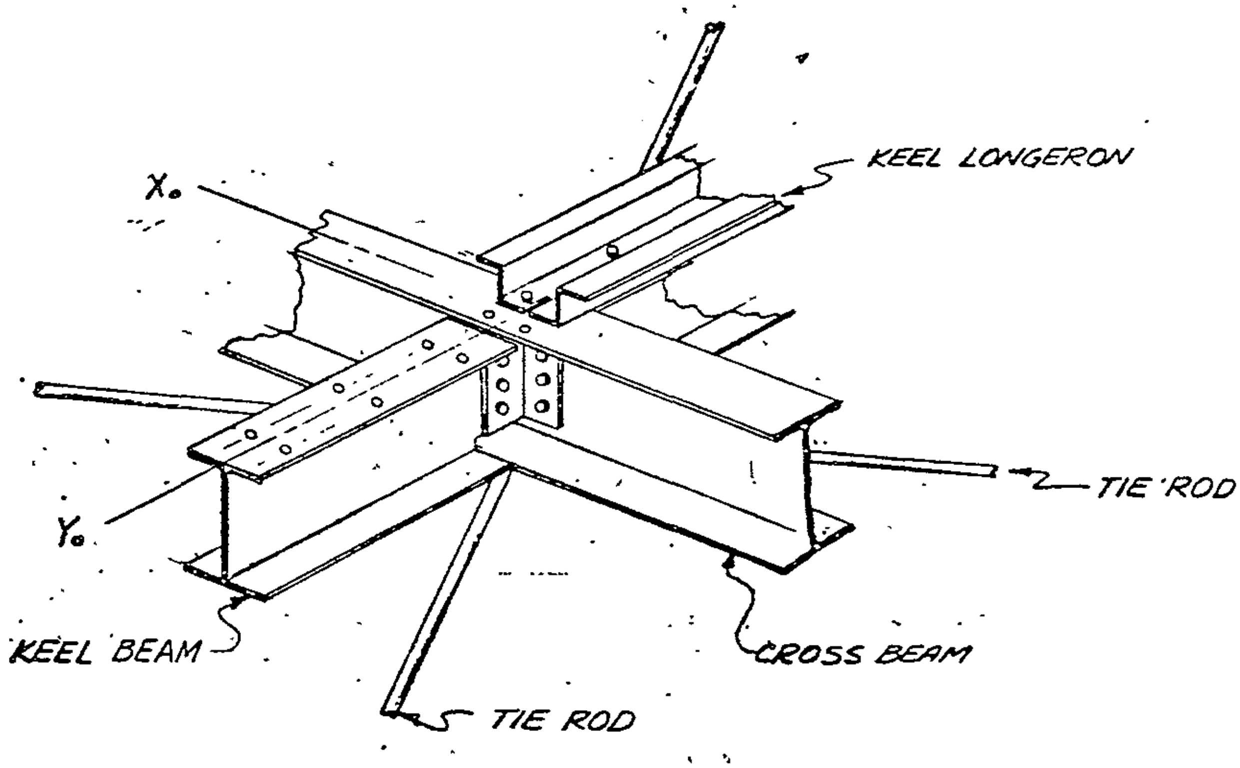
FOLDOUT FRAME 6

.500 PLATE
1.00 DIA. HOL



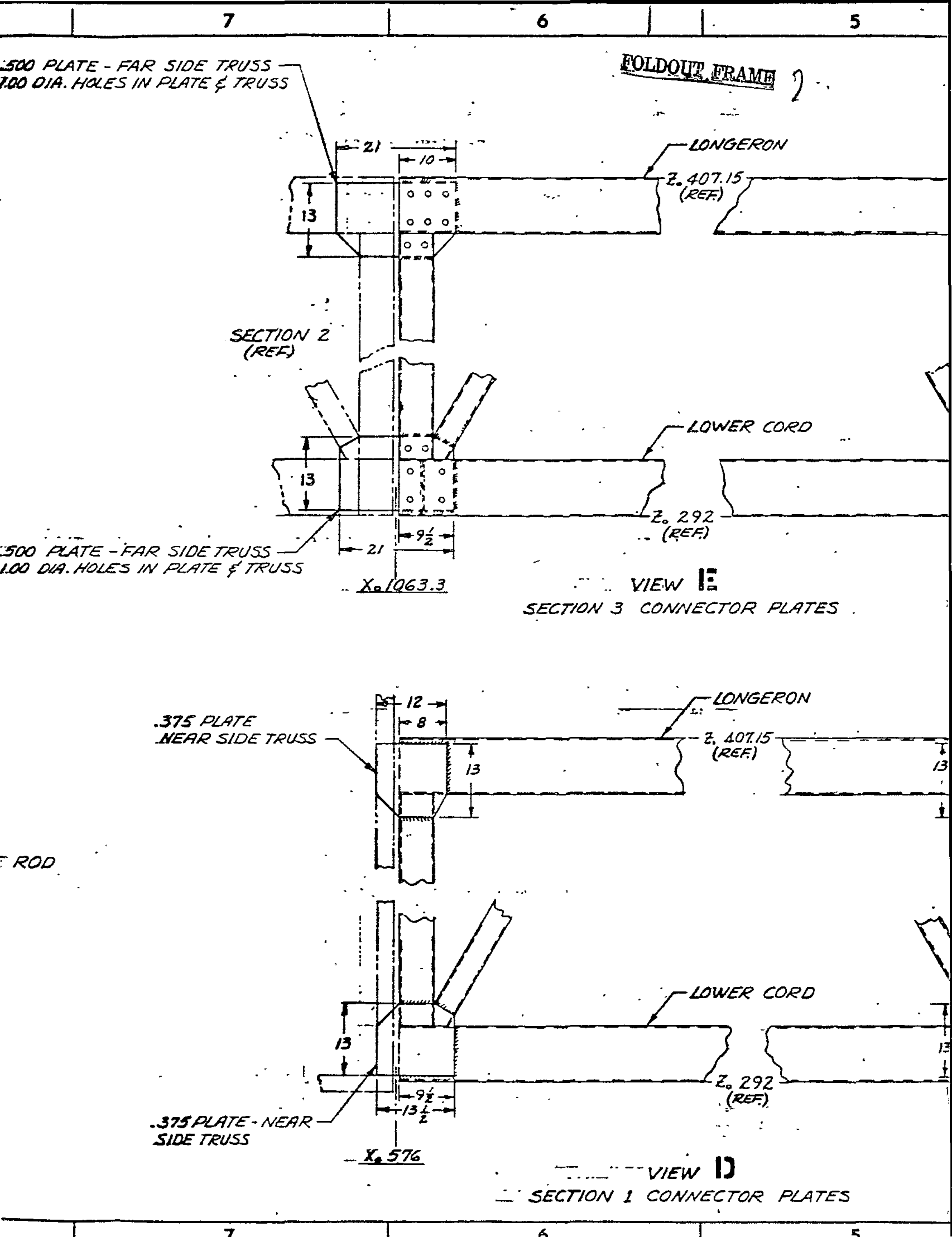
SECTION C-C FULL SIZE

.500 PLATE
1.00 DIA. HOL



TYPICAL KEEL ASSEMBLY

10 | 9 | 8


7
6
5
FOLDOUT FRAME 2
.500 PLATE - FAR SIDE TRUSS
.00 DIA. HOLES IN PLATE & TRUSS
21
10
LONGERON
Z. 407.15
(REF)
13
SECTION 2
(REF)
LOWER CORD
13
Z. 292
(REF)
.500 PLATE - FAR SIDE TRUSS
1.00 DIA. HOLES IN PLATE & TRUSS
21
9 1/2
X. 1063.3
VIEW E
SECTION 3 CONNECTOR PLATES
12
8
LONGERON
.375 PLATE
NEAR SIDE TRUSS
Z. 407.15
(REF)
13
ROD
LOWER CORD
13
Z. 292
(REF)
9 1/2
13 1/2
.375 PLATE - NEAR
SIDE TRUSS
X. 576
VIEW D
SECTION 1 CONNECTOR PLATES
7
6
5

5 4 3

FOLDOUT FRAME 8

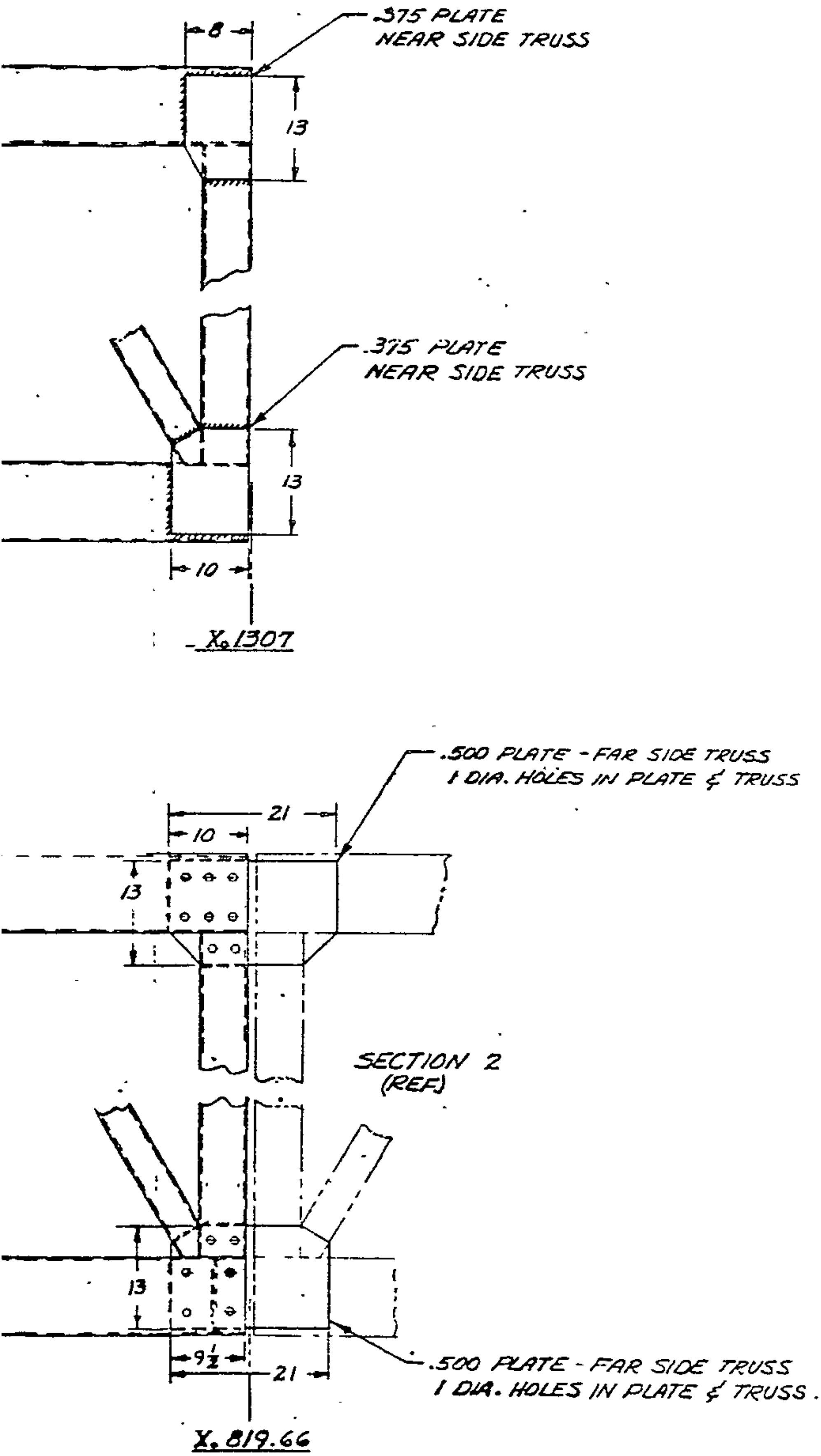


FIGURE 6-5 HORIZONTAL IVE PRIMARY STRUCTURE SECTION ASSEMBLY

Warren Truss panel layout shown in Figure 6-6 minimizes the unsupported span of the longeron and provides an efficient load distribution path from the longeron through the lower cord to the floor supports. The truss is constructed as a welded 20 foot long assembly composed of tubular steel members meeting the ASTM-500 Grade B material specification. A 6x10 inch rectangular section was selected for the longeron to accommodate the combined bending and torsion loads induced by the payload. A similar section was selected for the lower cord in order to physically match the depth of the wide flange cross beams. Gusset plates on each side of the intersecting members were used to distribute loads across the joint and to resist eccentric loading in the upper cord. Two diagonal tie rods in conjunction with a longitudinal keel beam provide stability to the horizontal cross beams (Figure 6-7).Diagonal knee braces (shown in Figure 6-8) stabilize the trusses. Leveling screws are provided at the section corners to assist in the alignment of the structure.

6.2.1.2 Mid-Body Section Interconnection Design

The three mid-body sections of the structure are joined together with a bolted splice plate type connection at the longeron and lower cord members to form a continuous 60 foot long structure. The design of the connectors between Sections 1 and 2 and 2 and 3 (Figure 6-9) were dictated by the loading conditions of the vertical IVE configuration. The weight of the payload, the IVE structure, optional equipment, aft crew station and personnel were considered in establishing the maximum design loads. The sections are bolted together at the longeron and lower cord members with double splice plates as illustrated in Figure 6-10. The splice plates are welded on opposite sides of the truss structure for adjacent sections to form an overlapping joint during assembly. The attach hole pattern was pre-drilled through the welded plate and longeron and lower chord members. These holes are used as a guide for drilling the splice plates on initial assembly. The splice plates and longerons were bolted together with one inch diameter bolts.

6.2.1.3 Structure Sizing

A static loads and stress analysis was performed using the NASTRAN program for sizing the structural members. For member sizing information refer to Vol. II Appendix B, Horizontal IVE Hardware Utilization List. See Section 7 of this report for discussion of the structural analysis.

The critical design drivers and impact on the structural members are presented in Table 6.1. The buckling stability in the Vertical IVE configuration and the bending/torsional loading in the Horizontal IVE configuration were the prime drivers in sizing the structural members.

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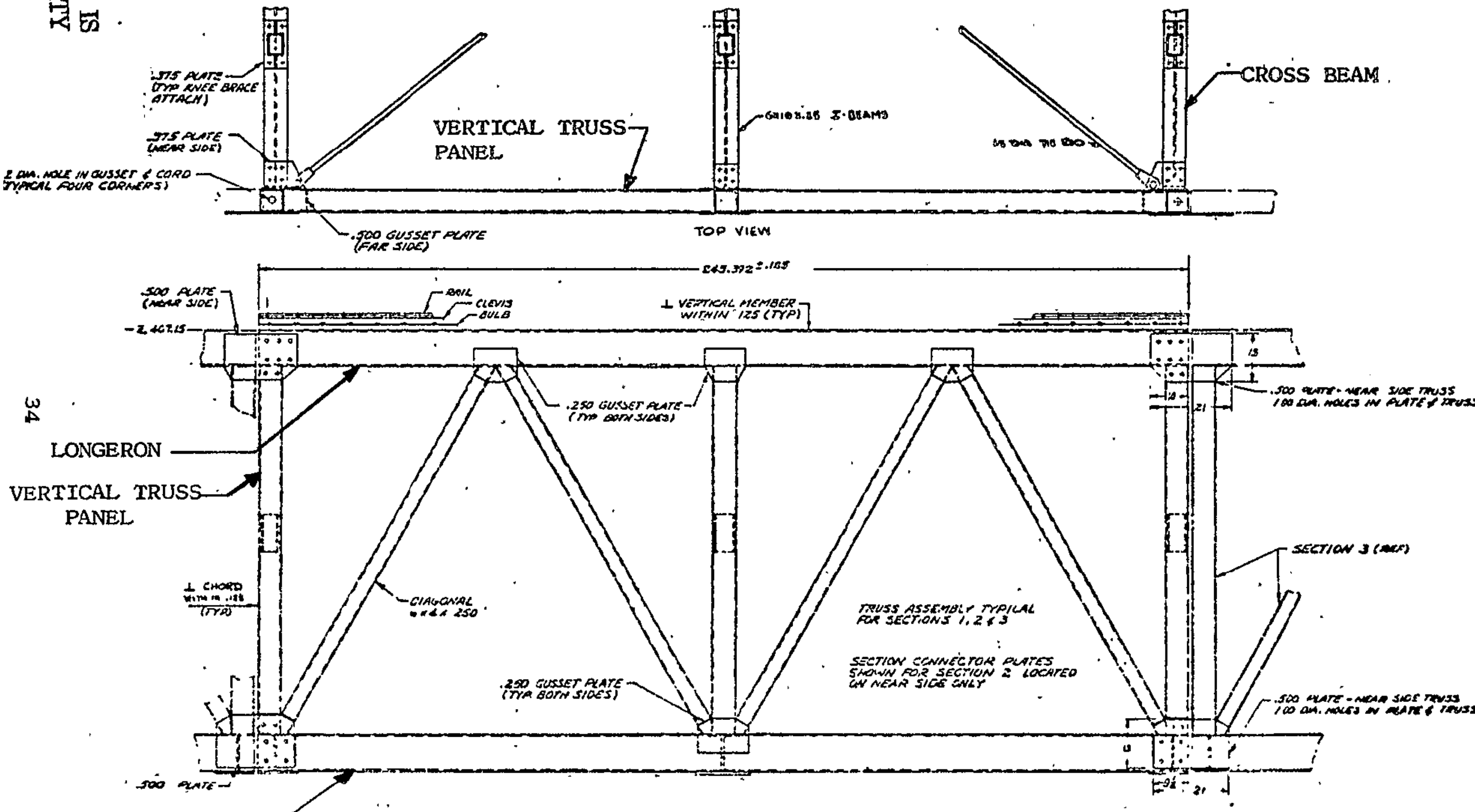


FIGURE 6-6 IVE PRIMARY STRUCTURE - TRUSS DESIGN

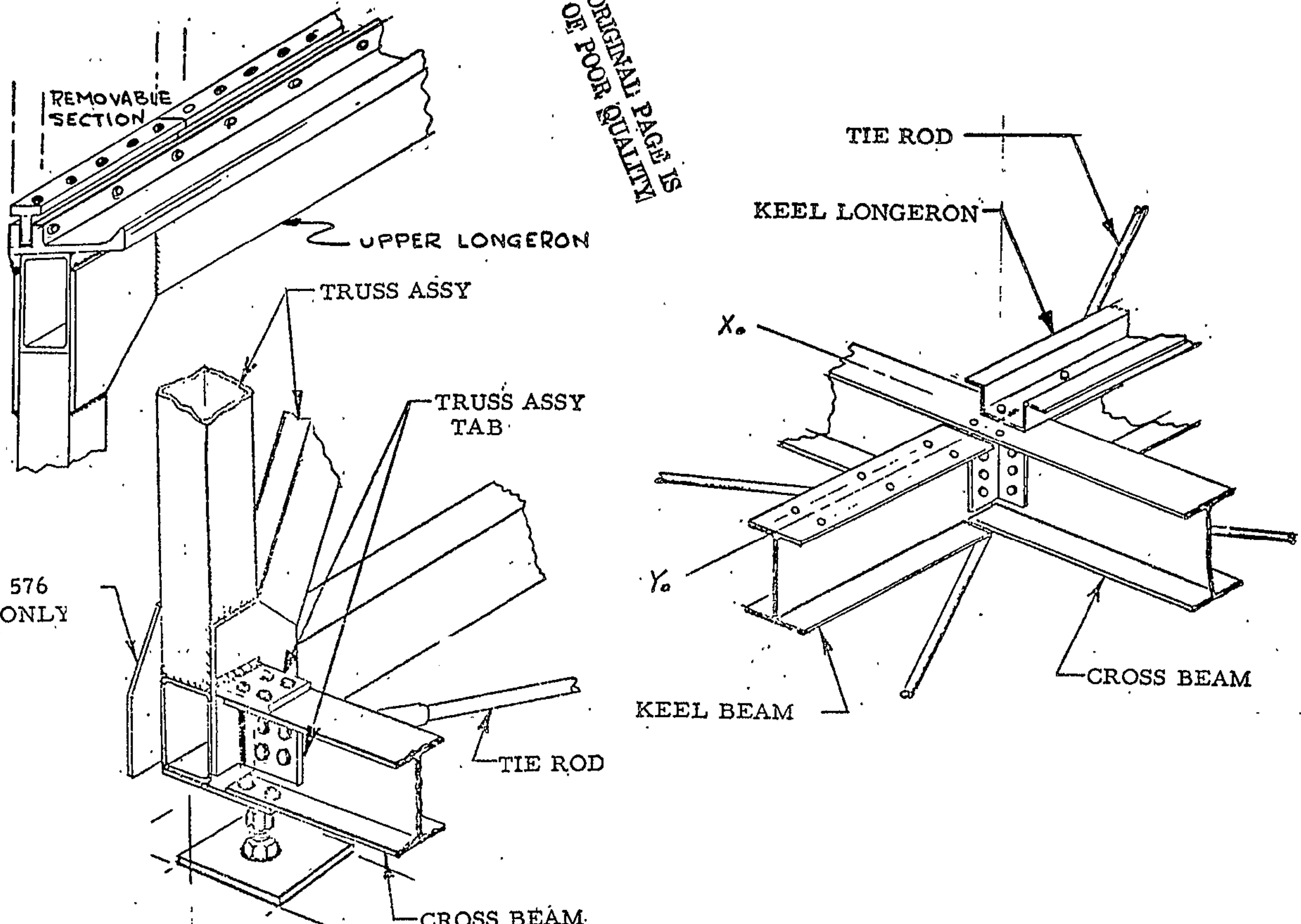


FIGURE 6-7 DETAILS OF IVE STRUCTURE DESIGN

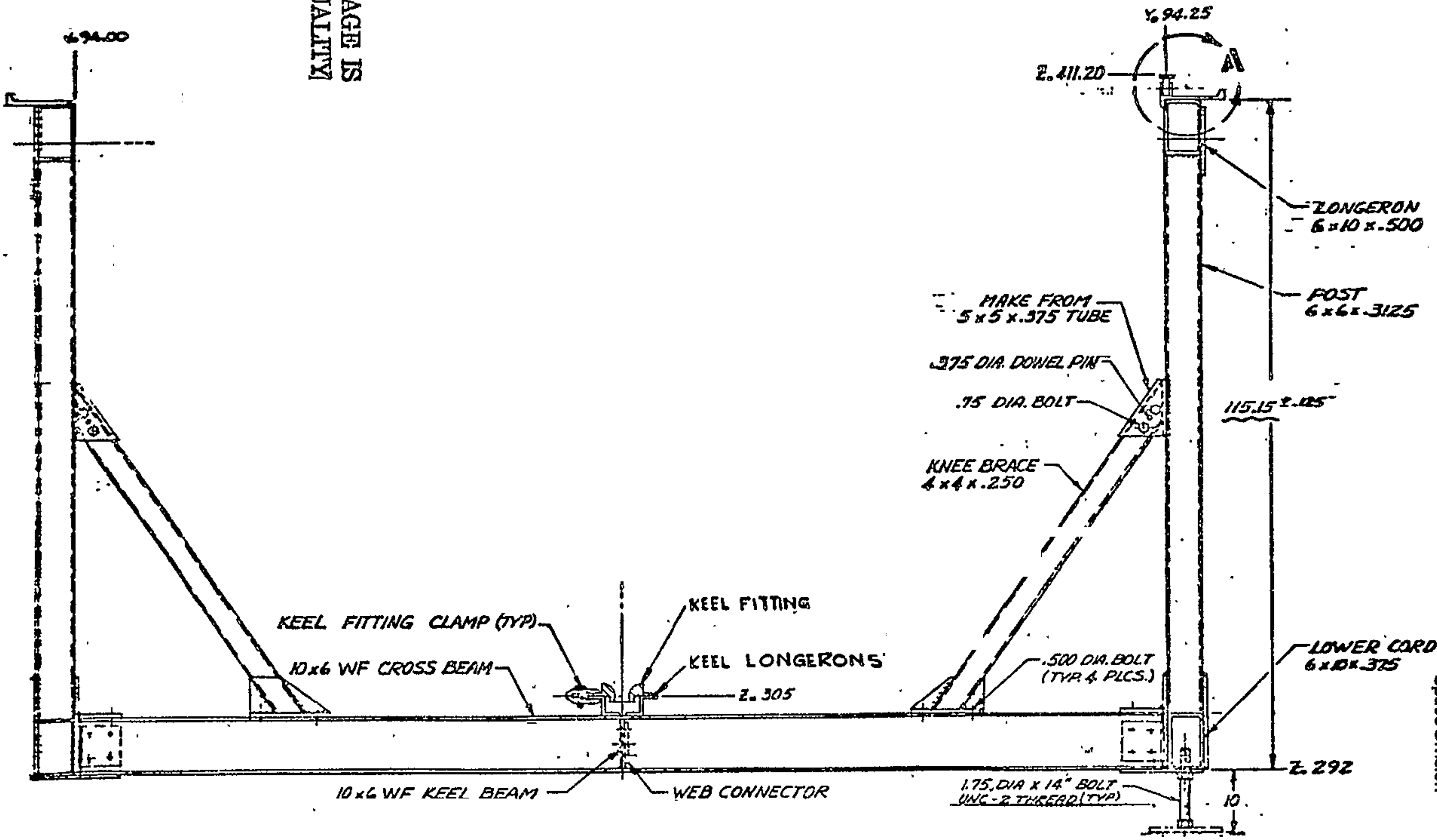
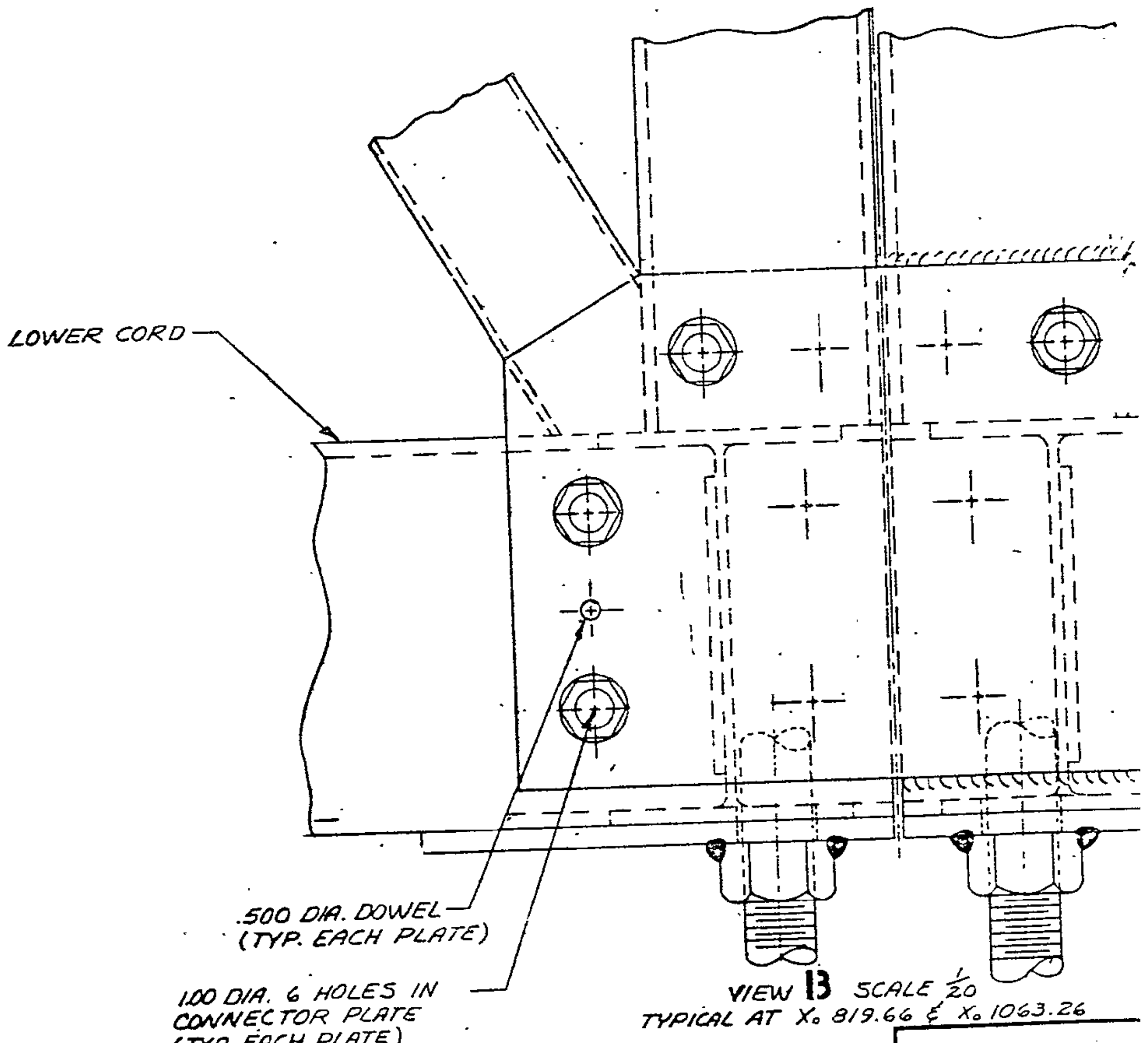


FIGURE 6-8 CROSS SECTION - IVE PRIMARY STRUCTURE

GE IS
ALITY

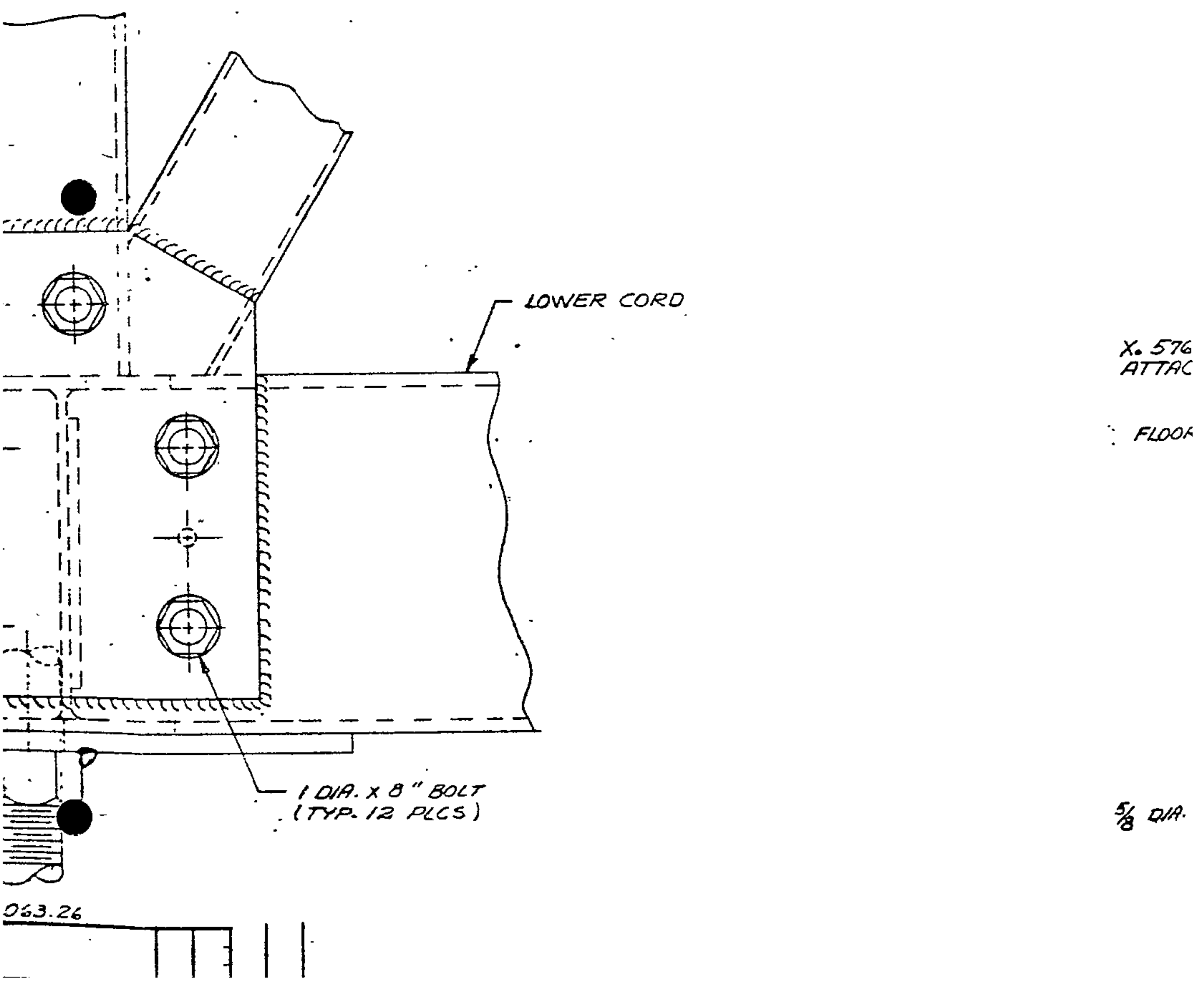
RAM



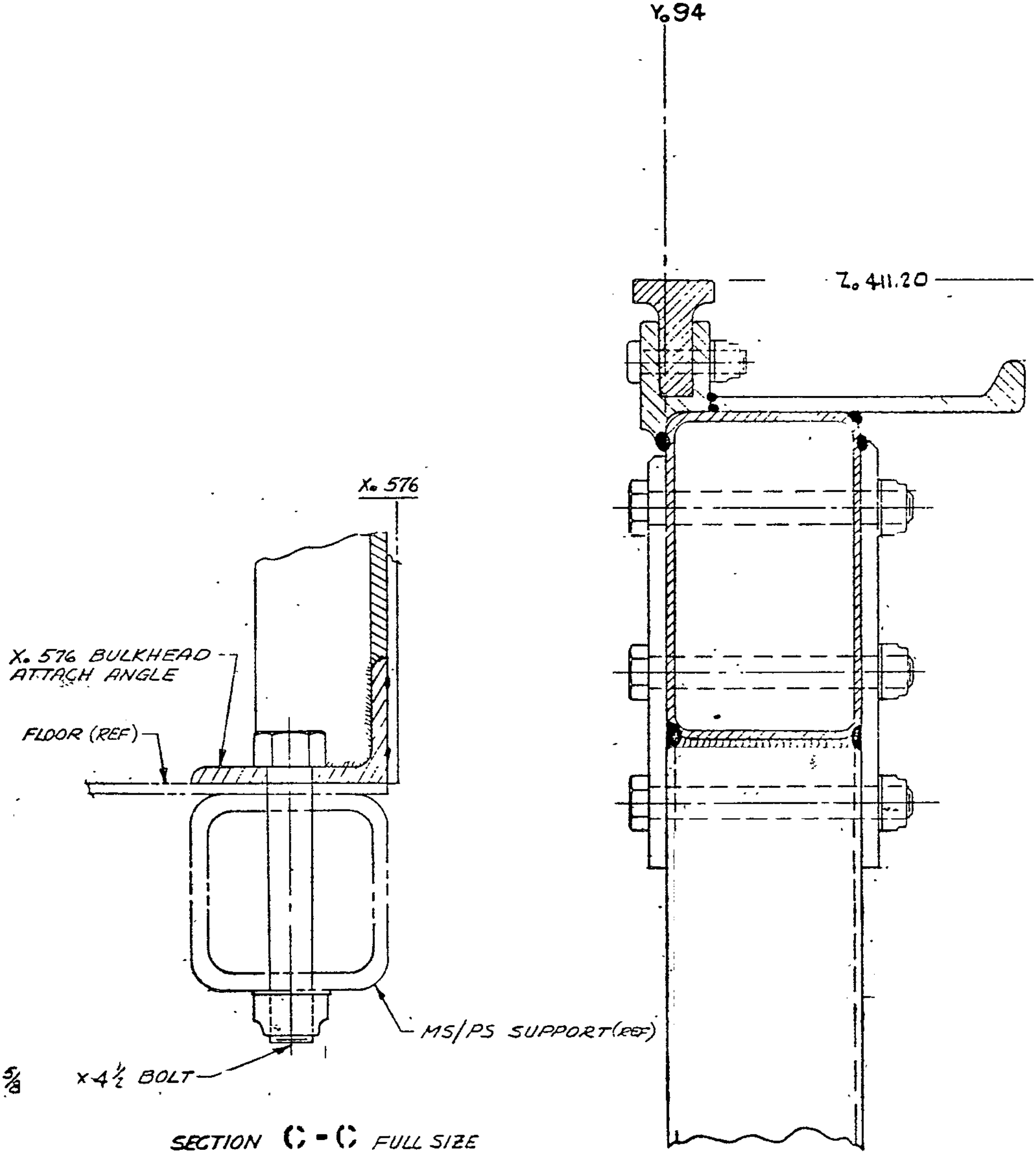
VIEW B SCALE 1/20
TYPICAL AT X_o 819.66 & X_o 1063.26

17 16 15

FOLDOUT FRAME 2

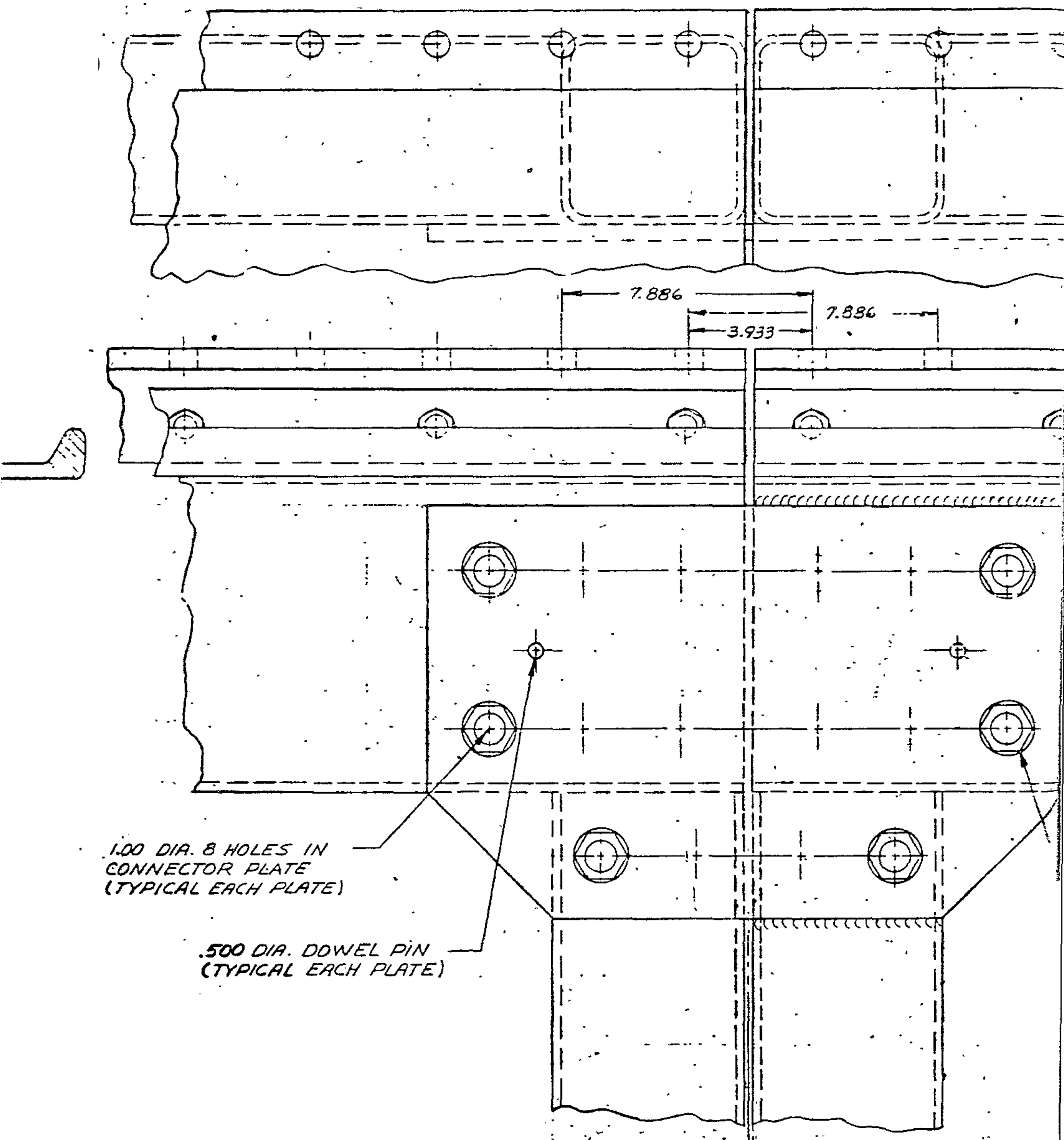


FOLDOUT FRAME 3



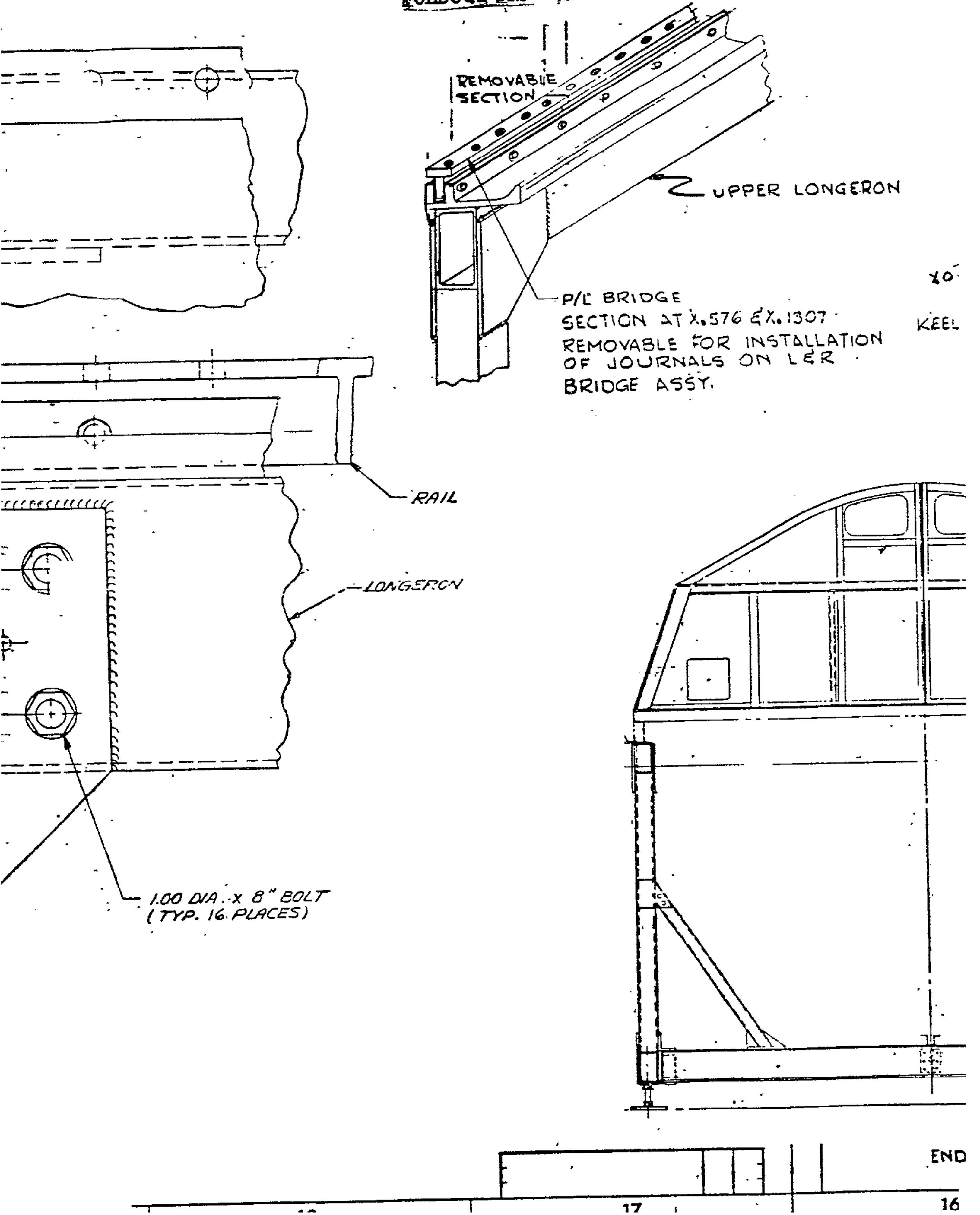
SECTION C - C FULL SIZE
TYPICAL BULKHEAD ATTACH

FOLDOUT FRAME 4

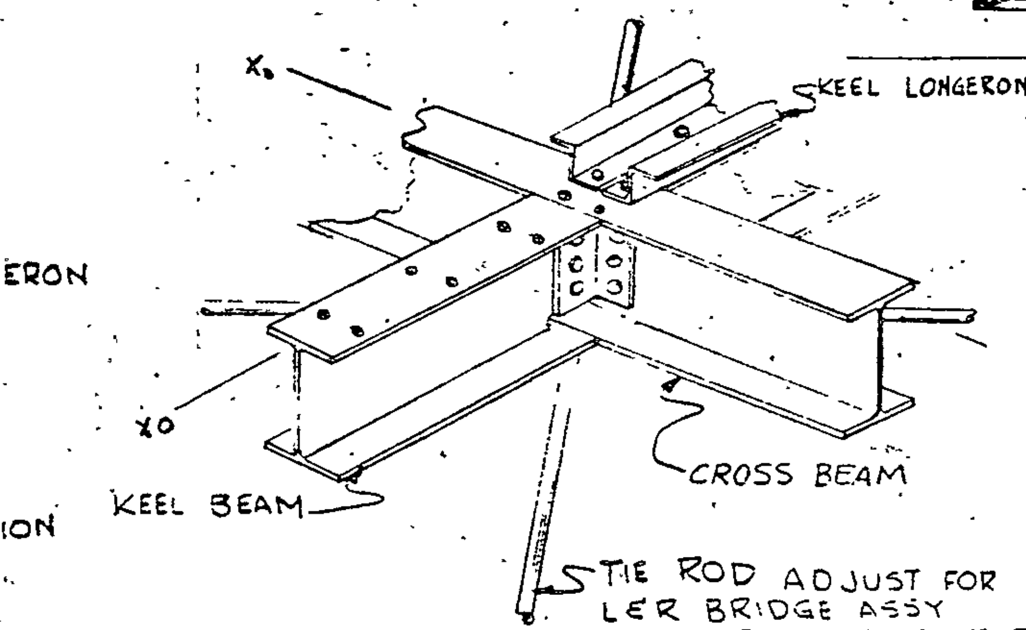


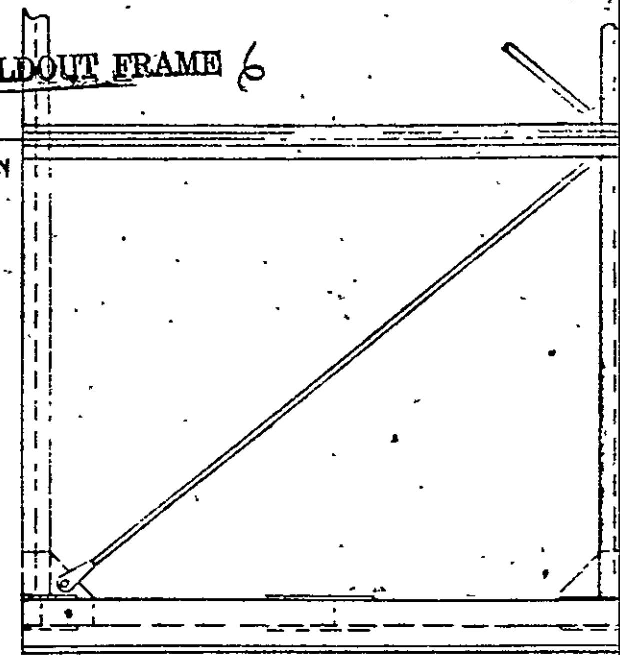
VIEW A SCALE $\frac{1}{20}$
TYPICAL X. 819.66 & X. 1063.26

FOLDOUT FRAME

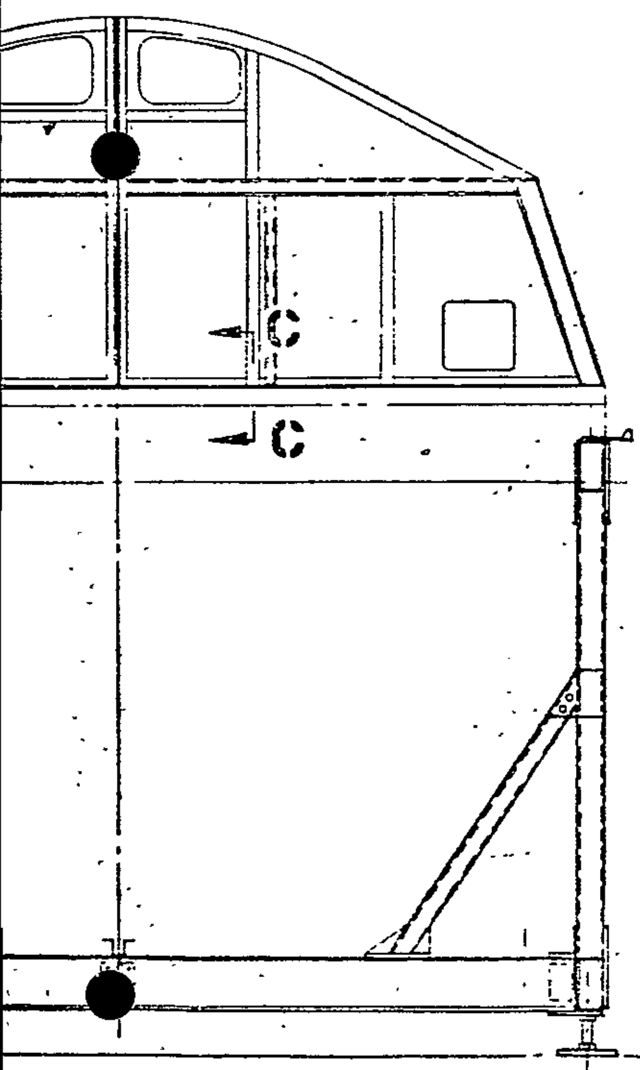


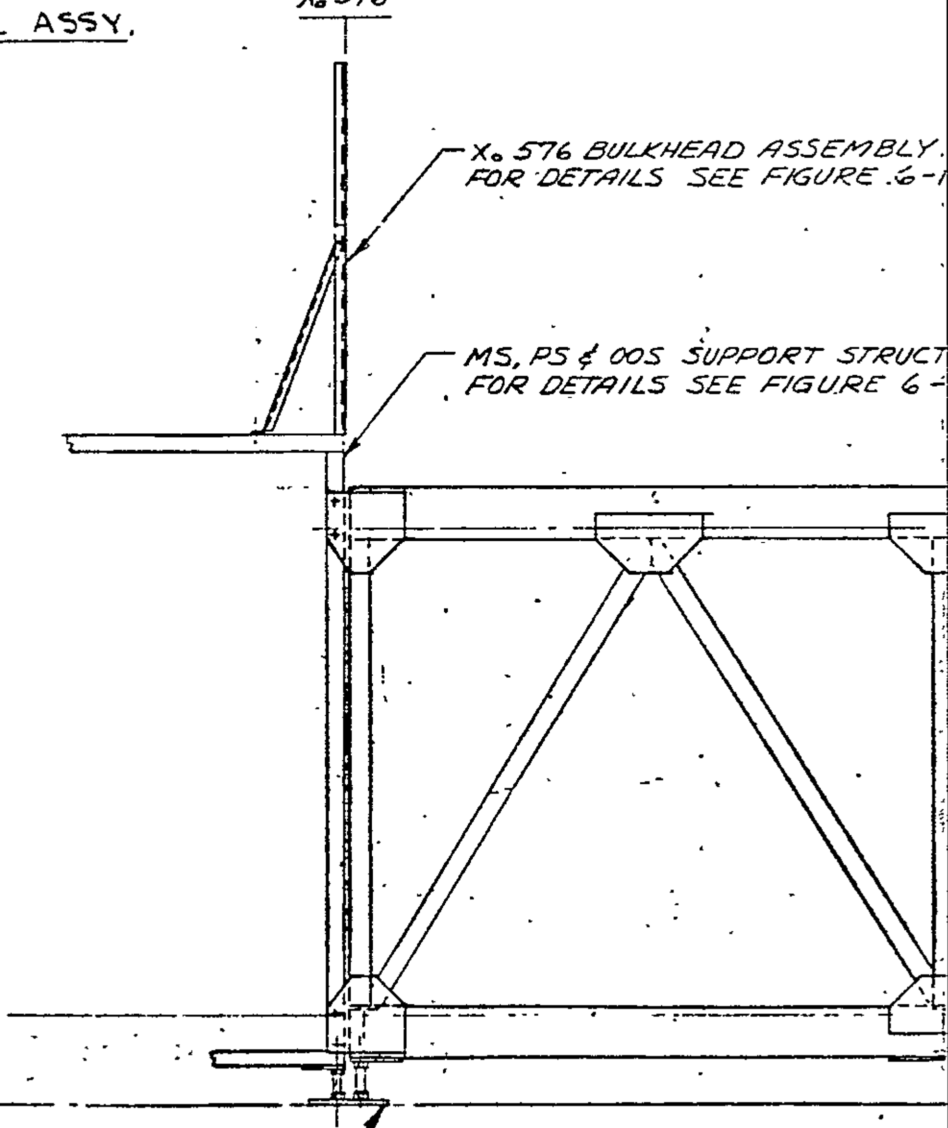
FOLDOUT FRAME 6





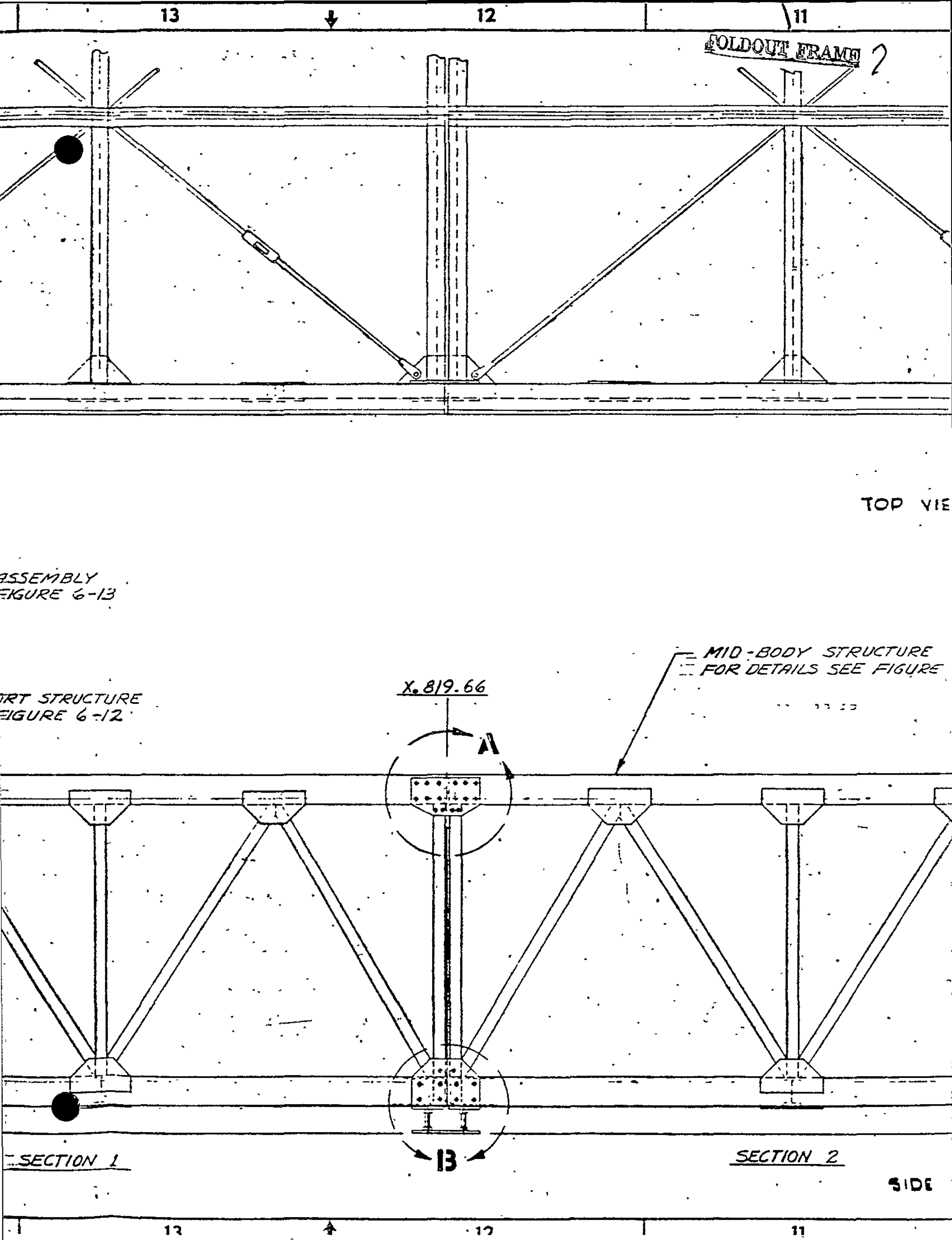
TYPICAL KEEL ASSY.



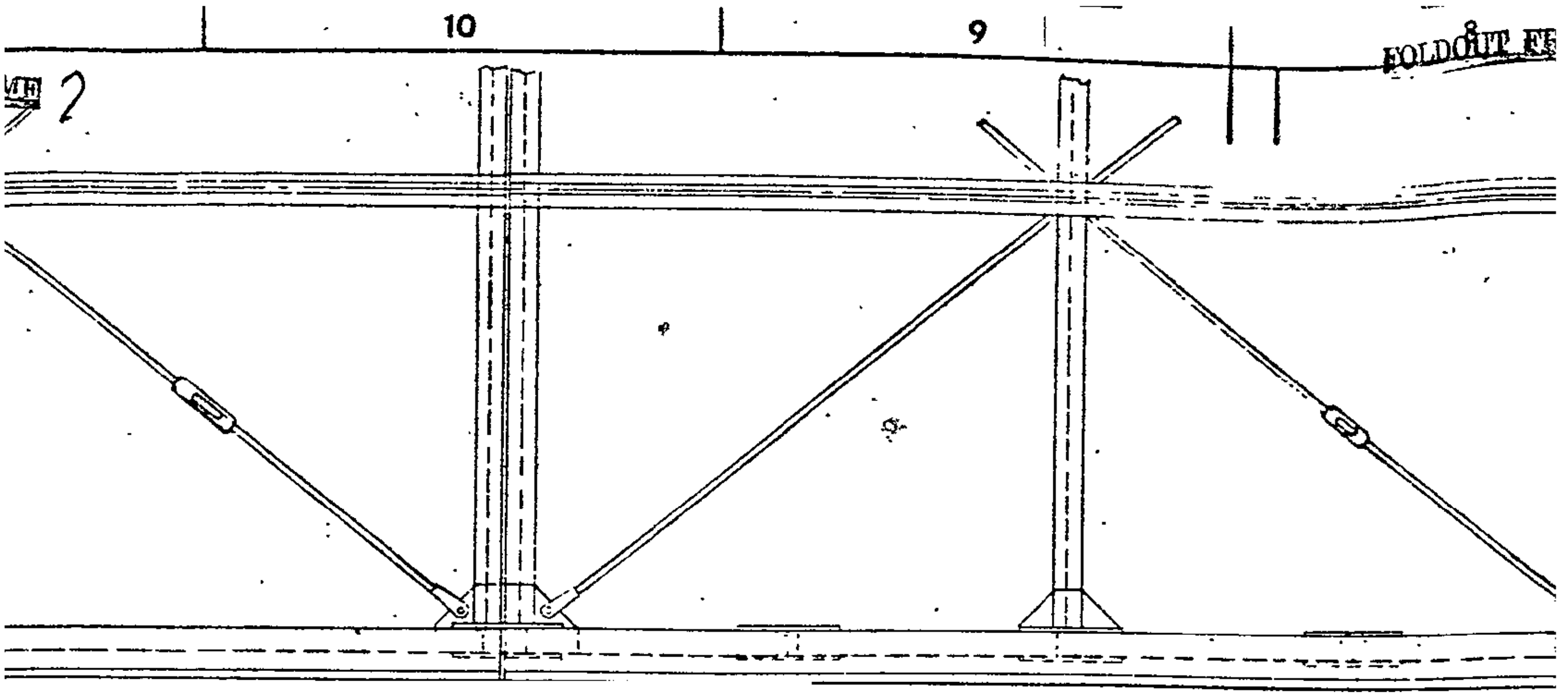


SECTION

END VIEW Xo 576 BULKHEAD

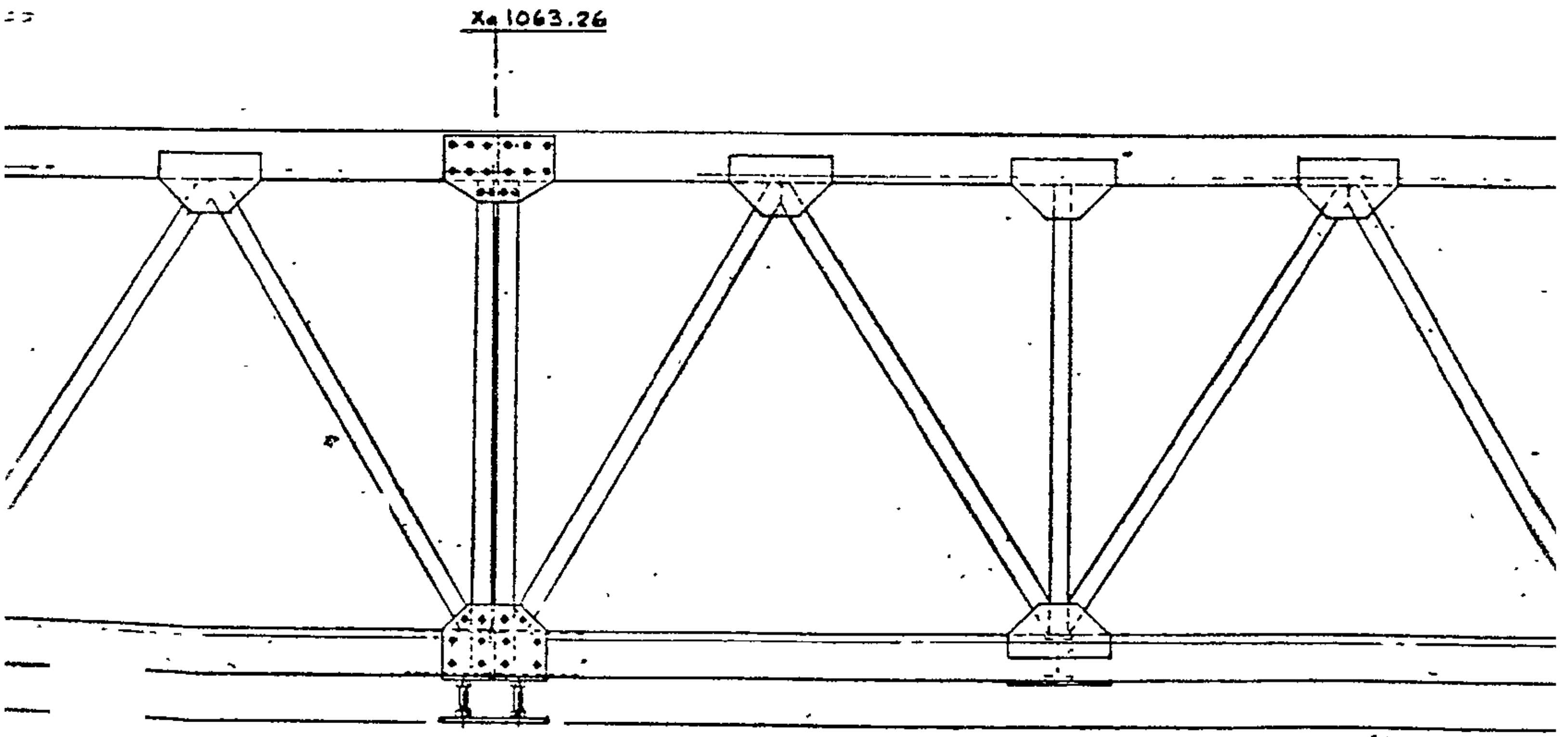


13
12
11
FOLDOUT FRAME 2
TOP VIE
ASSEMBLY
FIGURE 6-13
MID-BODY STRUCTURE
FOR DETAILS SEE FIGURE
X. 819.66
RT STRUCTURE
FIGURE 6-12
A
B
SECTION 1
SECTION 2
SIDE
13
12
11



TOP VIEW

TRUCTURE
EE FIGURE 6-9

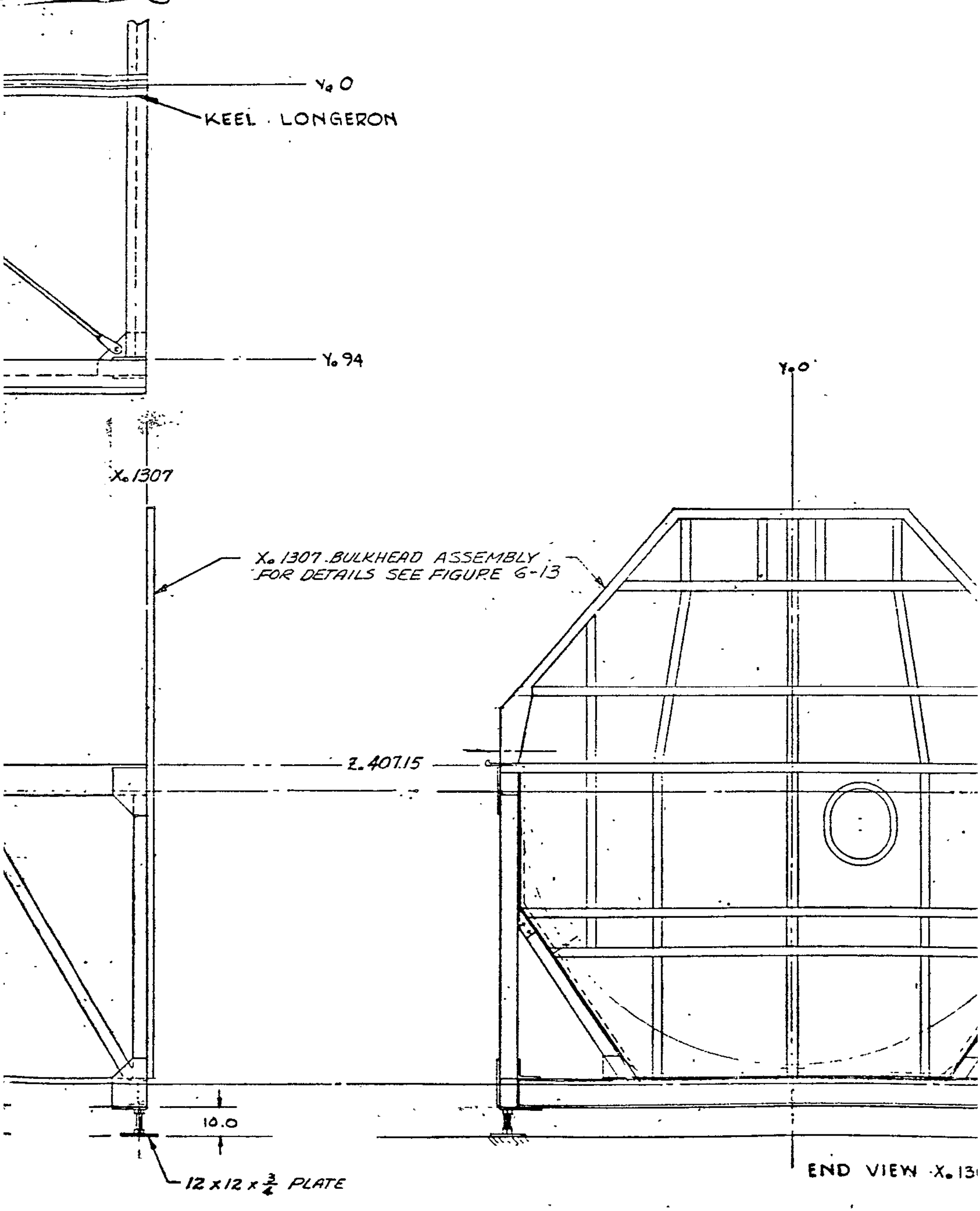


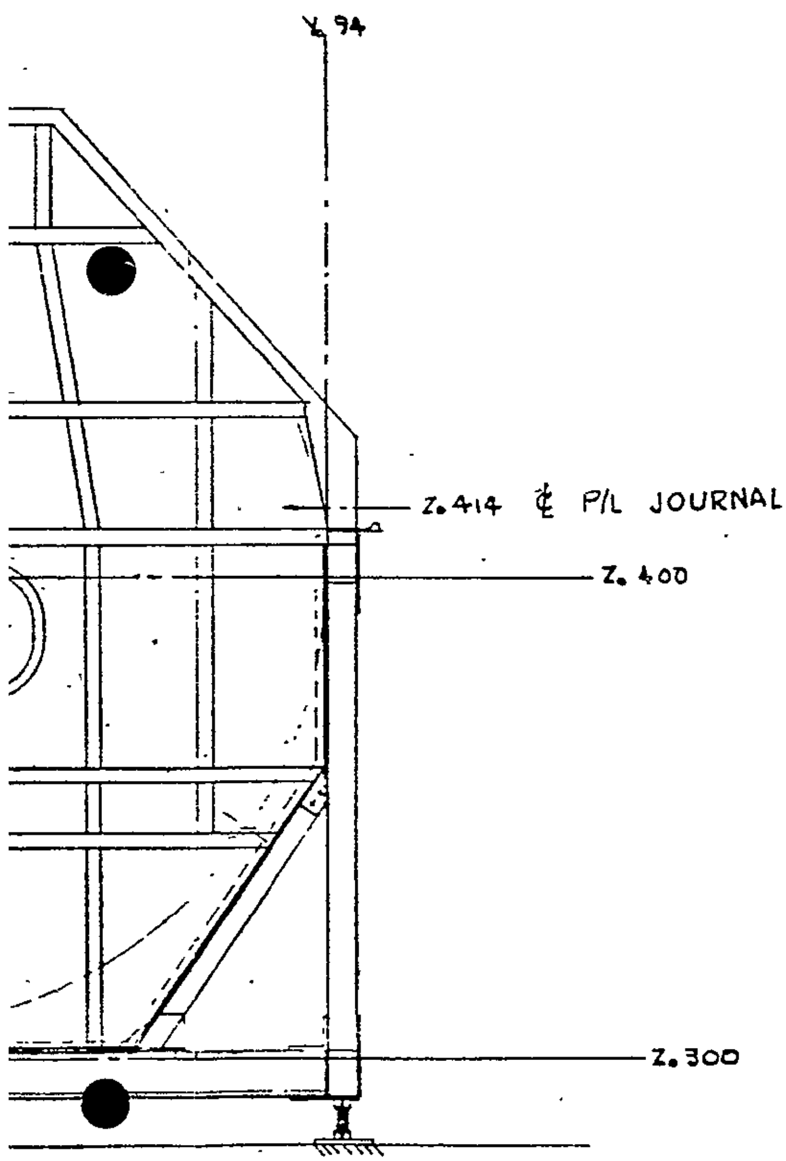
SECTION 3

SIDE VIEW

10 9 8

OLDOUT FRAME





VIEW X. 1307 BULKHEAD

FIGURE 6-9 HORIZONTAL IVE PRIMARY STRUCTURE ASSEMBLY

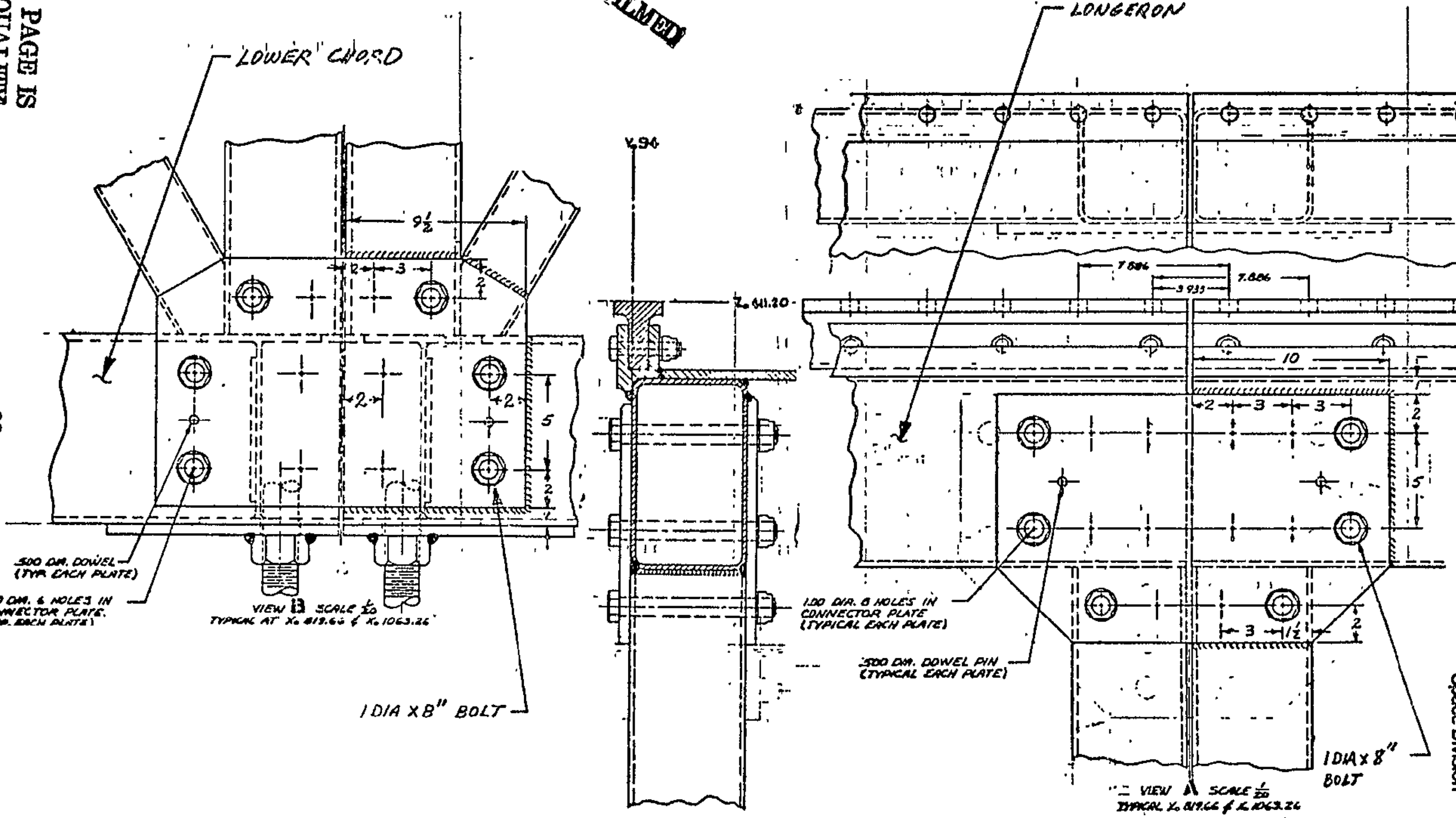


FIGURE 6-10 IVE PRIMARY STRUCTURE - SECTION CONNECTION

TABLE 6.1 IVE STRUCTURE DESIGN DRIVERS

STRUCT ELEMENT	DIMENSION	IVE	DRIVING CONSIDERATION
LONGERON	WIDTH	V**	BUCKLING STABILITY
	DEPTH	H	PAYLOAD LOCATED BETWEEN LONGERON SUPPORT PTS
	t*	H	TORSION - ECCENTRICITY OF P/L ATTACHMENT
VERTICAL POST	WIDTH	V	BUCKLING STABILITY
	DEPTH	H	PAYLOAD BETWEEN LONGERON SUPPORT PTS
	t	H	BENDING AT END POSTS
DIAGONAL POST	WIDTH & DEPTH	H	PAYLOAD AT DIAGONAL SUPPORT POINT
		V	STRUCTURAL STABILITY
LOWER CHORD	WIDTH & DEPTH	H	PAYLOAD AT POST SUPPORT POINT
		V	STRUCTURAL STABILITY
CROSS BEAM	DEPTH	V	STRUCTURAL STABILITY
KNEE BRACES	WIDTH & DEPTH	H	SIDE LOAD STABILITY
SECTION CONNECTION	t	V	STABILITY, IVE EQUIPMENT AND STRUCTURE "DEAD LOAD", PERSONNEL

*t - WALL THICKNESS
**V - VERTICAL IVE
H - HORIZONTAL IVE

The 6x10 inch upper longeron was the primary load carrying member in both the vertical and horizontal configuration. A bulb angle member and clevis mounting were added to the longeron to increase the lateral stiffness of the longeron in the vertical configuration to support a 65,000 pound payload (Figure 6-11). The clevis member mates with the bridge rail in a bolted tongue and groove type attachment which provides a direct compressive load patch from the payload journal fitting to the longeron box without loading the bolts attaching to the rail (Horizontal Configuration).

6.2.1.4 Bridge Rail Design

The bridge rail (Figure 6-11) was designed as a continuous member 20 feet long that bolted to the top of the primary structure sections. This removable feature allows the bridge rail to be easily replaced if damaged during operations or to accommodate an Orbiter related design change. Holes were drilled in the top of the rail to provide a basic 3.933 inch vernier adjustment of the payload journal fitting for the length of the cargo bay.

The continuous longeron design approach for payload attachment, enhances IVE operations requiring minimal effort to reconfigure from one payload to the next. A portion of the upper rail is removable at each end of the upper longeron so that addition/removal of payload attach fittings is facilitated (Figure 6-7). Relocation of upper longeron payload primary attach fittings is accomplished by removing the locking pins, sliding the fitting to a new location and inserting locking pins. The stabilizing fittings slide freely on the rail to any desired location.

6.2.1.5 Tolerance Control and Assembly

Dimensional control of the IVE structure is required in order to provide an accurate representation of the Orbiter mid-body payload interfaces. In addition, control of tolerance buildup is required to assure that the assembly and alignment of the structure is not adversely affected. The IVE tolerance control at the payload interfaces will be held to a factor of 3 better than the Orbiter. Tolerance build up over the 60 foot structure was controlled along the X and Z axes by the design of the splice plate connectors used between the three structural sections. In a similiar manner, splice plate connectors were used to control the build up in the Y axis within each section.

The use of a "top down" approach in the assembly of each section minimized the assembly tooling requirements and provided a simple, cost effective way to accommodate tolerance build up between the longeron and keel support members. This approach established the bridge rails on the longerons as a reference baseline from which all other members were

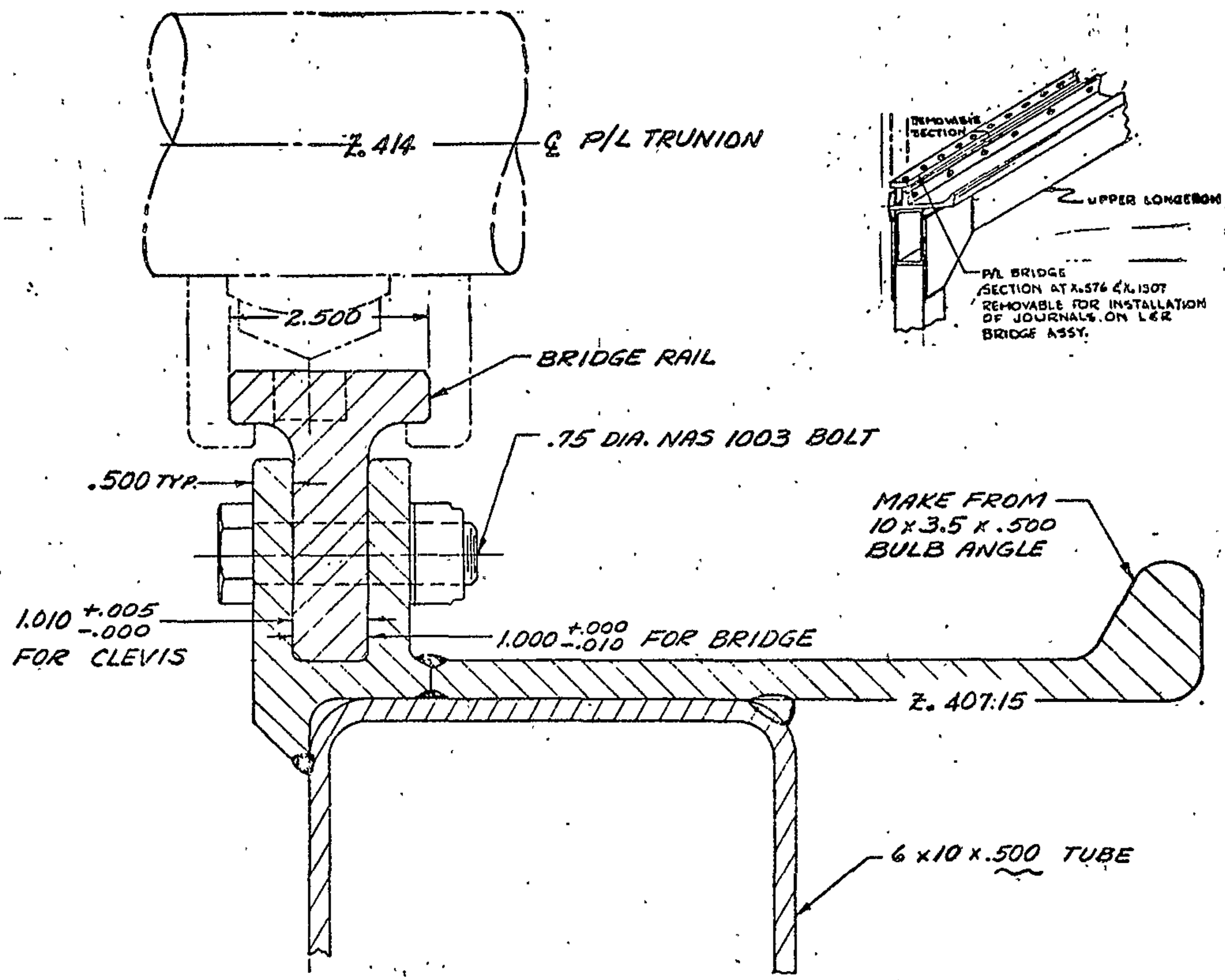


Figure 6-11. INTEGRAL LONGERON AND BRIDGE RAIL DESIGN

located with the aid of a master alignment tool. The tolerance build up associated with machining, welding the truss assemblies and assembly of the sections were accommodated at one point by locating the keel support members from the bridge rails with the master alignment tool. This greatly simplified the assembly and alignment of the structure and permitted the primary structure fabrication tolerances to be relaxed.

An assembly procedure for the horizontal IVE at the User's site was generated to help validate the engineering design of the structure. The procedure was based on the assumption that the IVE structure had previously been assembled, aligned, verified, disassembled and packaged for shipment by the Contractor prior to delivery to the User's site. Assembly was accomplished with the aid of 2 master alignment tools and 2 spreader bars provided by the Contractor and standard facility equipment such as overhead crane, forklift, optical transit, targets and levels provided by the User. A detailed step-by-step procedure for the in-field assembly and alignment of the IVE is presented in Volume II Appendix B, Horizontal IVE In-Field Assembly Procedure. A prime requirement for the design of the IVE structure was to ensure repeatibility of assembly and alignment at the User's site. This was accomplished by several features included in the design. Horizontal tie-rods were used to provide a convenient method of squaring the section assemblies. Adjustable floor jacks were used to allow vertical leveling of the truss assemblies. Tooling dowel pins were installed in all the critical bolted connections to provide a means of re-indexing each member to its original position.

6.2.2 Secondary Structure

The IVE secondary structure consists of the aft flight deck set (AFDS) support structure, the X_o576 and X_o1307 bulkhead assemblies and other non-load carrying structure to support the payload interface elements. Provisions for attachment of all secondary structure is incorporated in the primary structure during initial assembly, both for the standard IVE payload interfaces and those interfaces categorized as optional equipment. All the secondary structural components are attached to the primary strcuture with bolts or screws permitting simple replacement of parts that may be damaged or to accommodate Orbiter design changes.

Provisions for all secondary structure were incorporated in the primary structure primarily to maintain configuration control, assure interface fidelity, and maintain a class 100k clean room during in-field installation. Additional advantages occur due to the reduced time and effort required to install optional equipment in the field.

6.2.2.1 Aft Flight Deck Support Structure

The AFD Support structure provides (1) floor structure for the installation of the AFDS (2) a work platform for crew operations, (3) an attach structure to support the X_o576 bulkhead, (4) a vertical support structure for the payload wire trays at X_o576 (5) a support structure for cabling interconnecting the operators console with the AFDS and (6) mounting provisions for optional equipment and interfaces (example: X_o576 tunnel interface). The support structure consists of two modular welded tubular assemblies supported by leveling screws at the floor level and attached to the primary structure at X_o station 576 as shown in Figure 6-12. The two welded assemblies are identical in design and are sized to comply with commercial air freight volumetric constraints. Diamond plate floor panels are attached to the top of the structure at Z_o419. Access to the platform is provided by facility furnished equipment and is not part of the IVE. Welded handrail assemblies are attached to three sides of the floor panels and the outboard edge of X_o576 bulkhead to provide safety restraints for personnel.

6.2.2.2 X_o576 Bulkhead Assembly

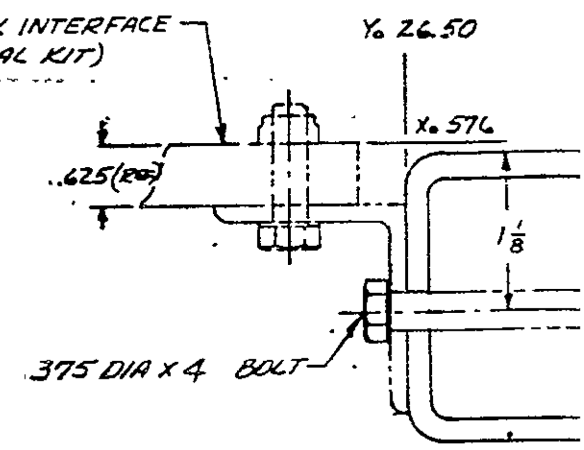
The X_o576 bulkhead provides (1) a structural enclosure for the aft end of aft flight deck (2) attach structure for the payload electrical feedthru panels and (3) aft observation window cutouts. The bulkhead design is a typical skin and stringer construction with provisions in the lower edge of the panel for bolting to the aft flight deck support structure. Details of the bulkhead are shown in Figure 6-13.

6.2.2.3 X_o1307 Bulkhead Assembly

The X_o1307 bulkhead provides (1) a structural enclosure for the aft end of the payload bay (2) attach structure for the payload electrical and fluid feed thru panels (3) access hatch cutout for aft fuselage and (4) support for attaching the T-O umbilical panel. The bulkhead design is a typical aluminum skin and stringer construction with an angle or channel used as an edge stiffener. The bulkhead is bolted to the primary structure longerons, vertical posts, knee braces and cross beam at X_o1307. Details of the bulkhead and installation are shown in Figure 6-13.

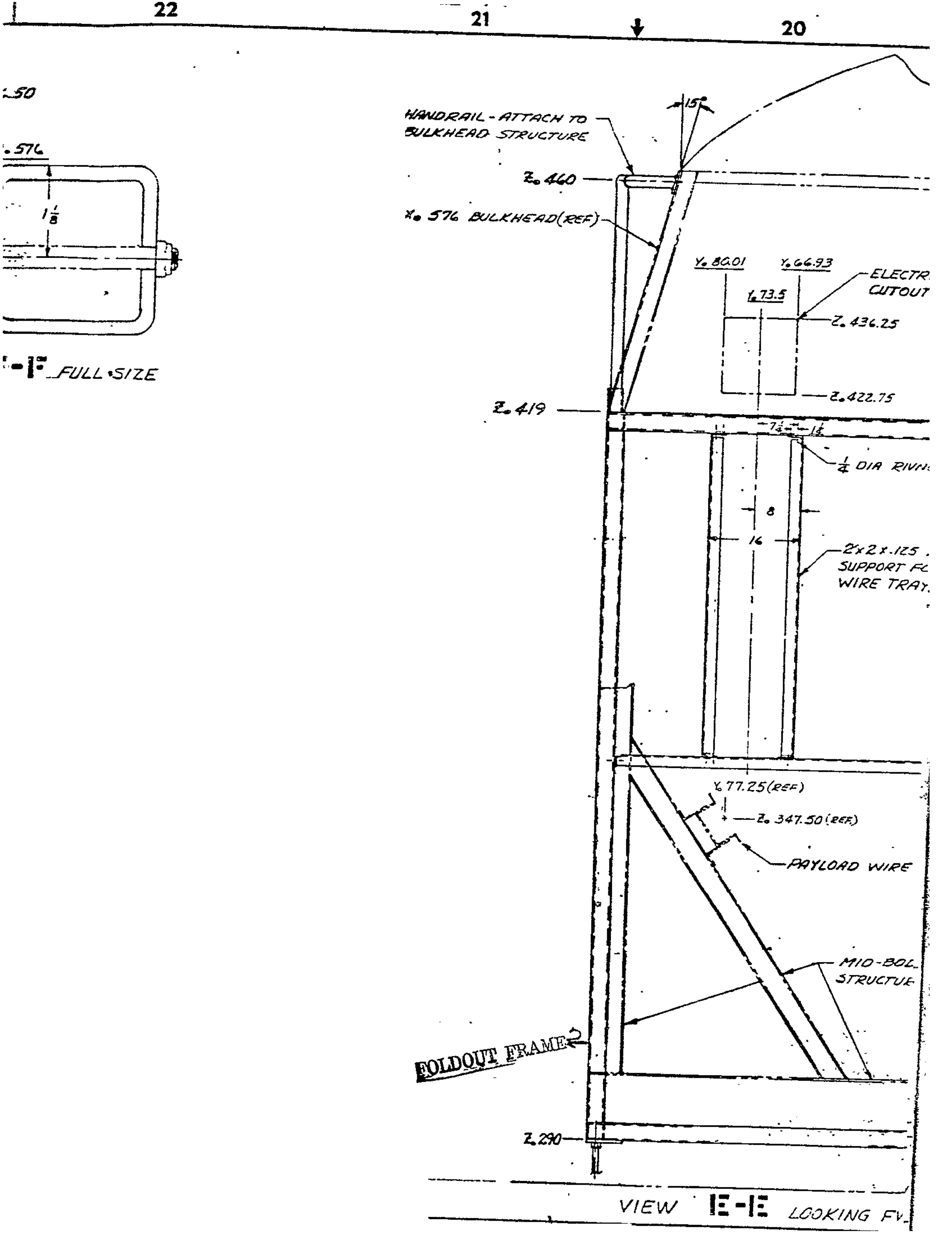
6.2.2.4 Primary and Stabilizing Longeron Non-Deployable Payload Bridge Fitting

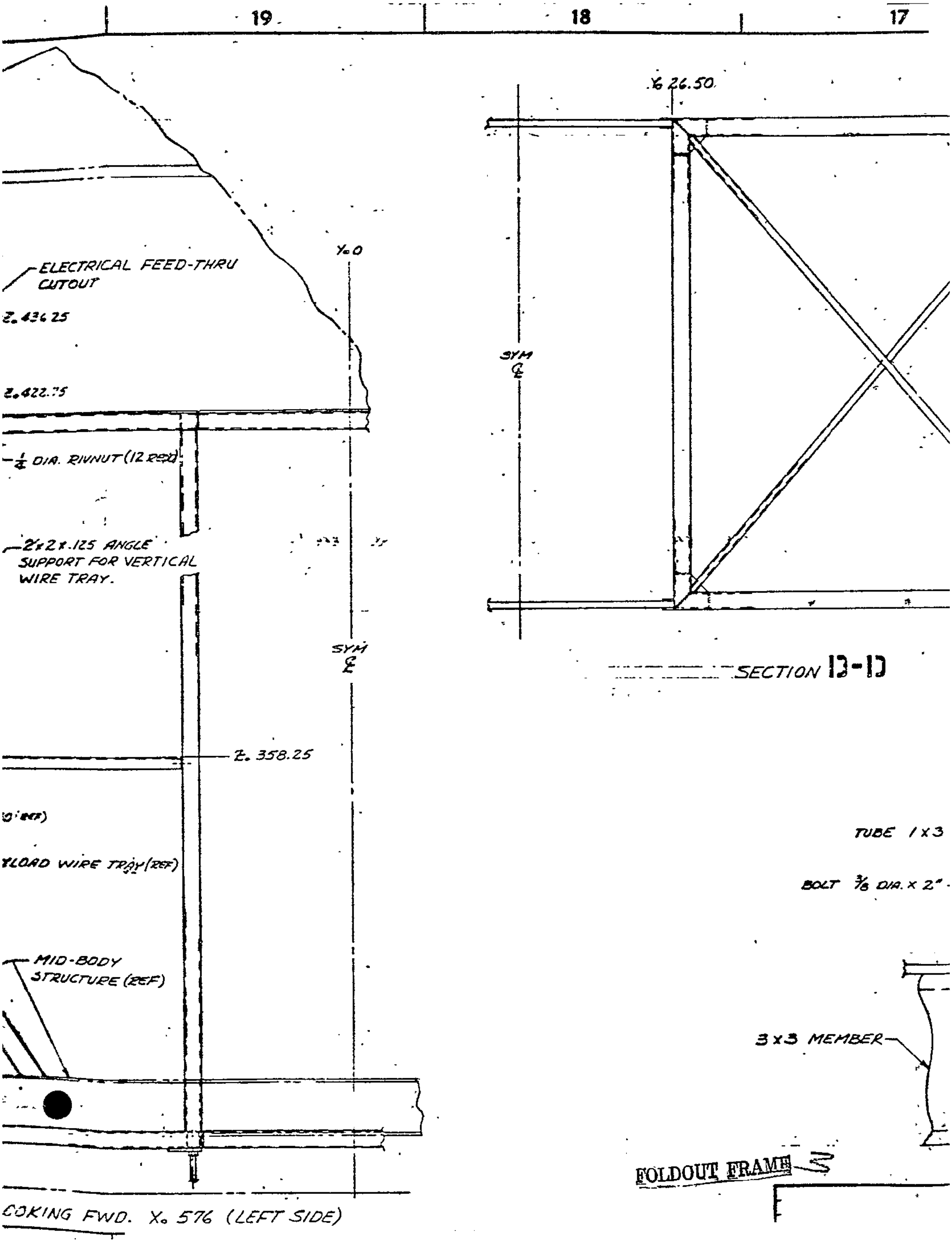
The payload journal fitting provides the interfacing mechanism between the payload trunnion and the bridge rail on the IVE structure.



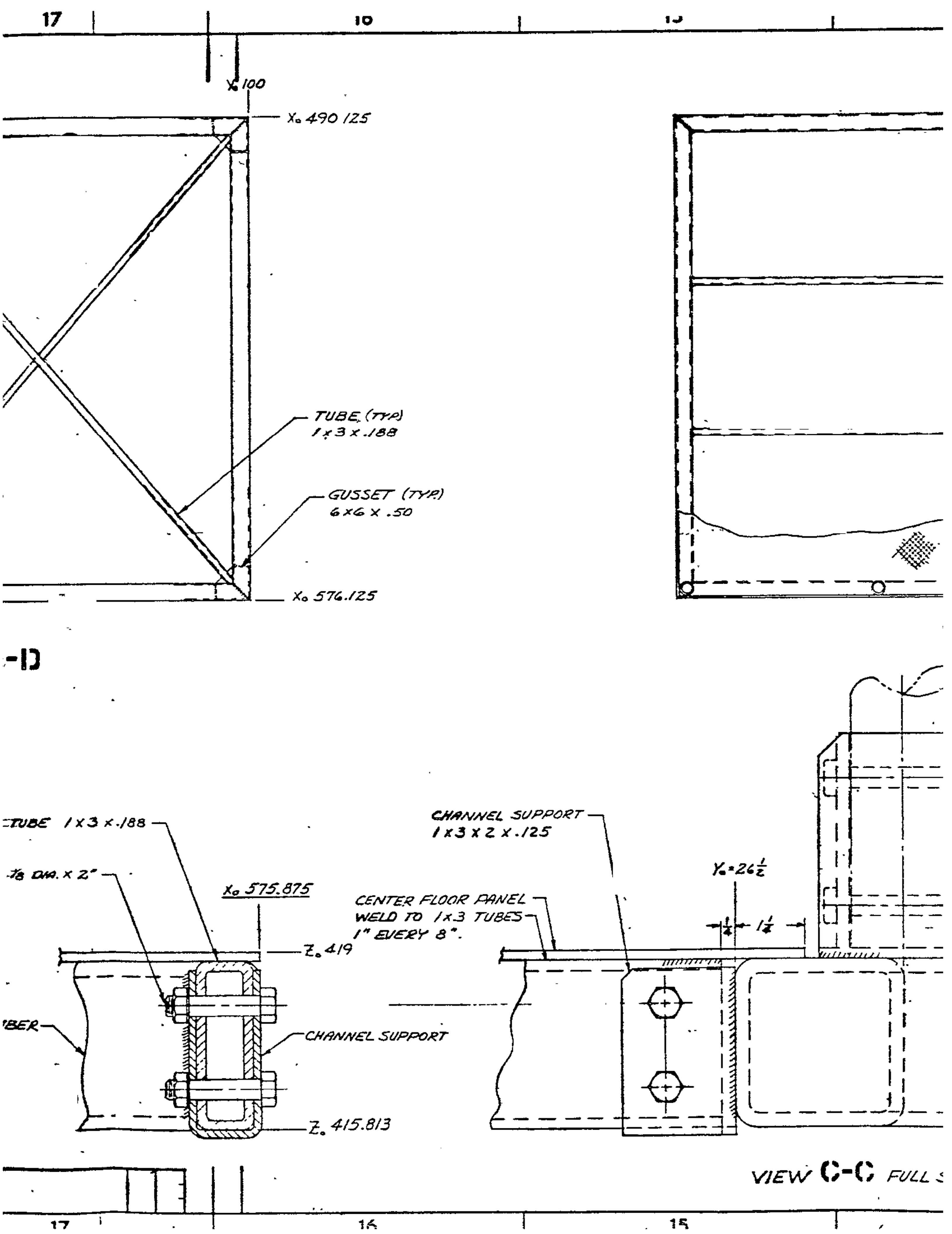
SECTION F-F

FOLDOUT FRAME

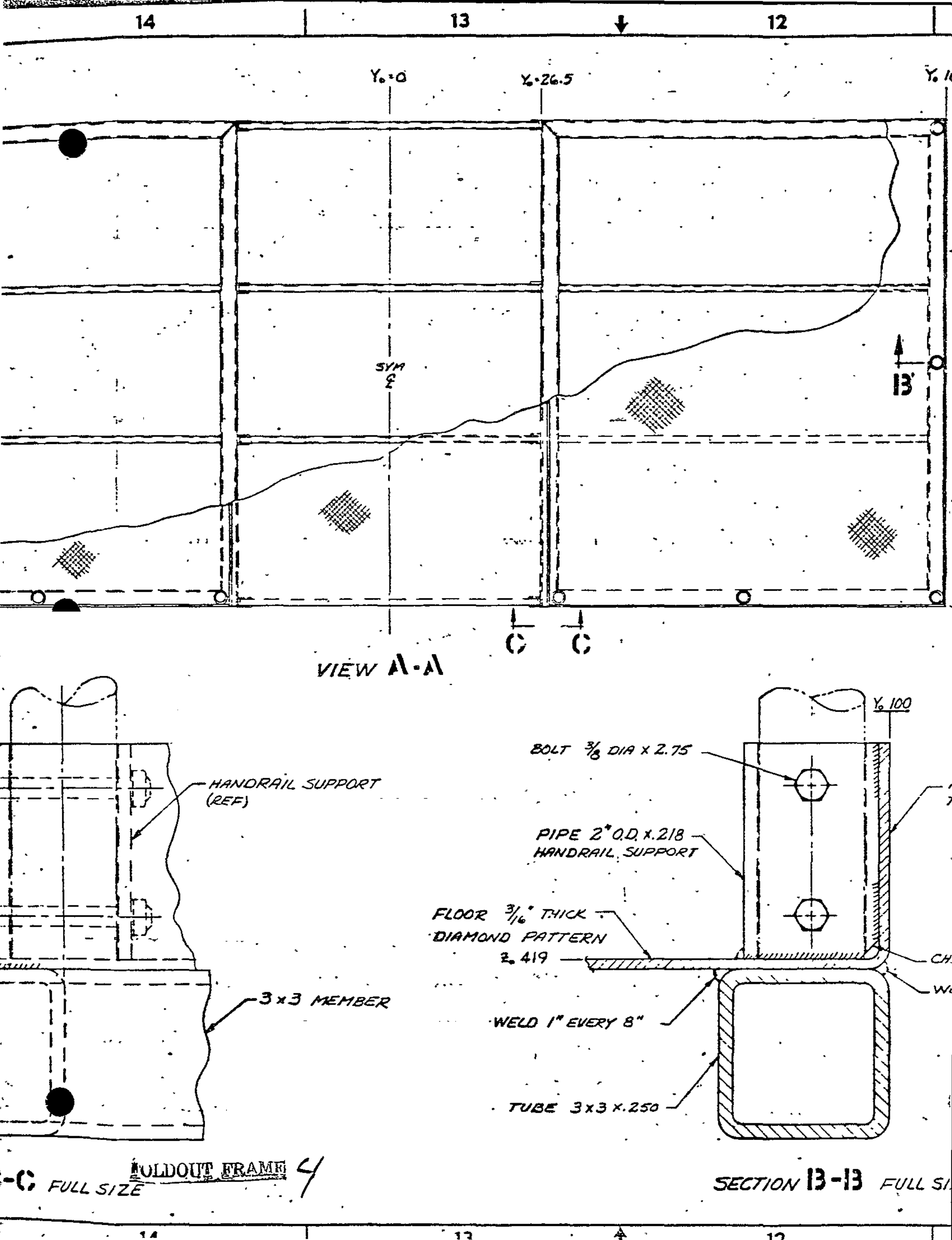

22
21
20
.50
.576
$1\frac{1}{8}$
F-F FULL SIZE
HANDRAIL - ATTACH TO BULKHEAD STRUCTURE
15°
Z. 460
X. 576 BULKHEAD(REF)
Y. 80.01
Y. 66.93
Y. 73.5
ELECTR CUTOUT
Z. 436.25
Z. 422.75
Z. 419
$\frac{1}{4}$ DIA RIVN
8
16
2x2x.125 SUPPORT FC WIRE TRAY
Y. 77.25 (REF)
Z. 347.50 (REF)
PAYLOAD WIRE
MID-BOL STRUCTUR
FOLDOUT FRAME 2
Z. 290
VIEW E-E LOOKING FW

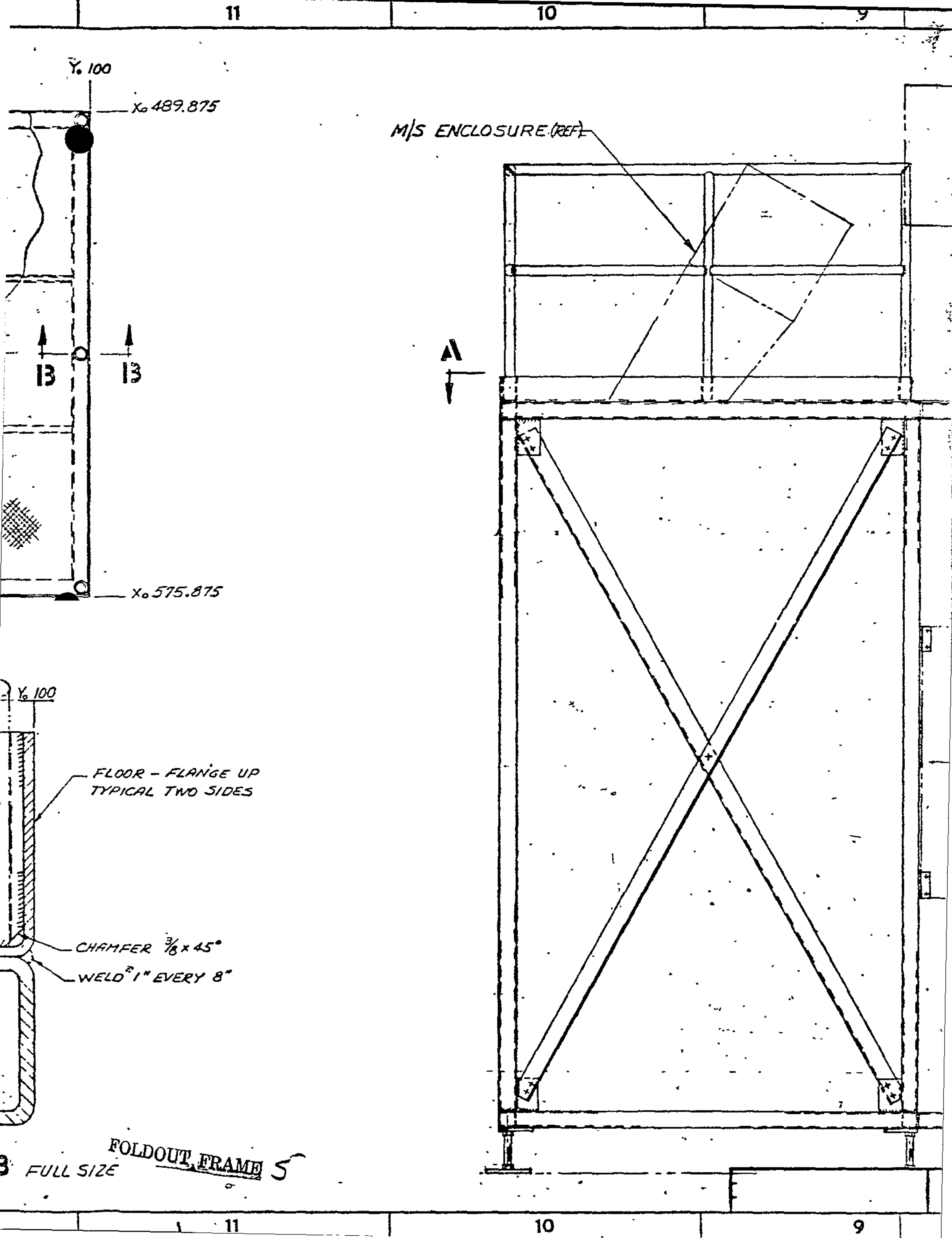


FOLDOUT FRAME 3

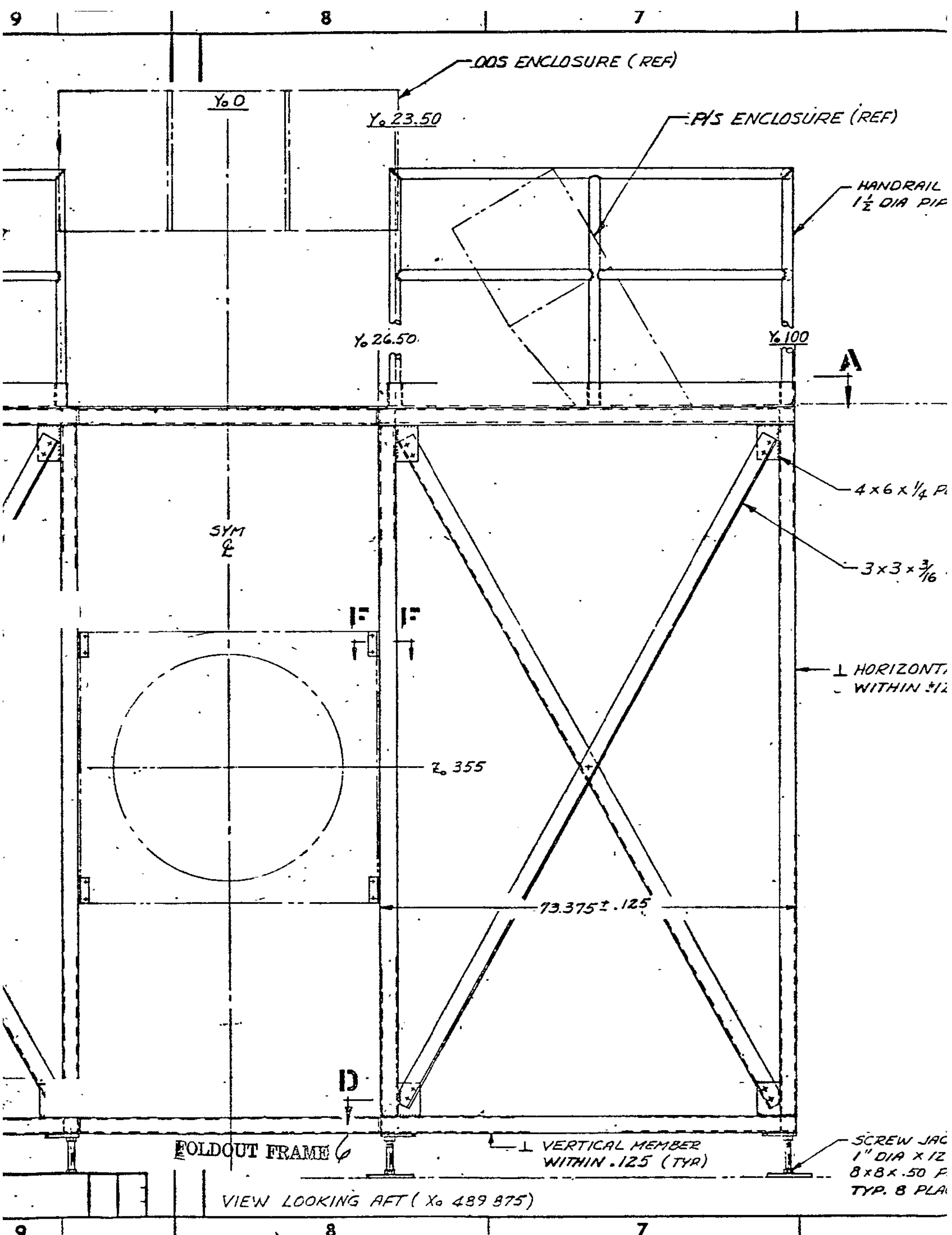


17
16
15
X_o 100
X_o 490.125
TUBE (TYP)
1 x 3 x .188
GUSSET (TYP)
6 x 6 x .50
X_o 576.125
-D
TUBE 1 x 3 x .188
DIA. x 2"
X_o 575.875
Z_o 419
BER
CHANNEL SUPPORT
Z_o 415.813
CHANNEL SUPPORT
1 x 3 x 2 x .125
CENTER FLOOR PANEL
WELD TO 1 x 3 TUBES
1" EVERY 8".
Y_o = 26 1/2
1/4
1 1/4
VIEW C-C FULL

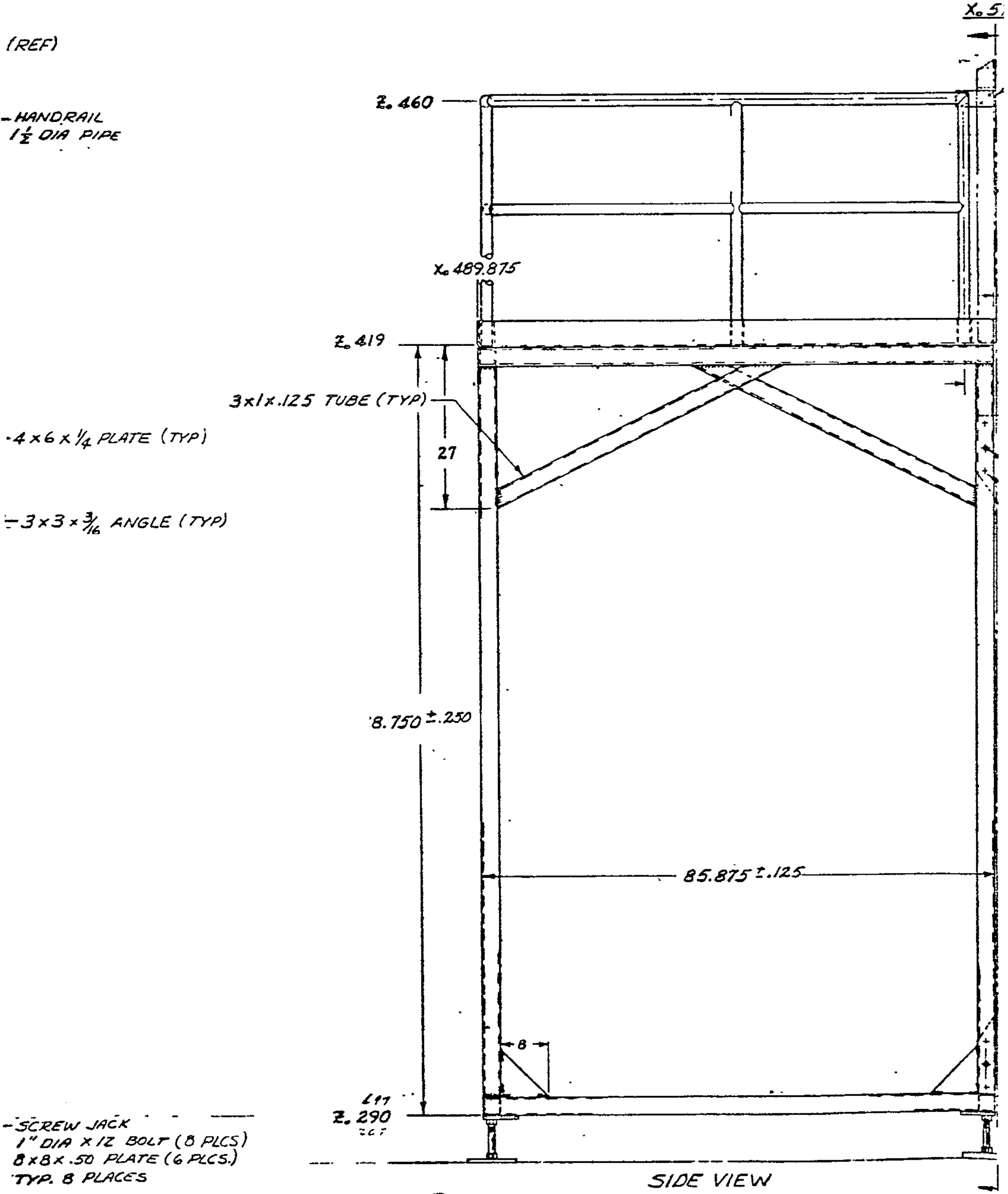

14
13
12
Y₀=0
Y₀=26.5
SYM
℄
B
C C
VIEW A-A
HANDRAIL SUPPORT
(REF)
3 x 3 MEMBER
-C FULL SIZE
Y₀ 100
BOLT 3/8 DIA x 2.75
PIPE 2" O.D. x .218
HANDRAIL SUPPORT
FLOOR 3/16" THICK
DIAMOND PATTERN
Z₀ 419
WELD 1" EVERY 8"
TUBE 3 x 3 x .250
SECTION B-B FULL SI
FOLDOUT FRAME 4



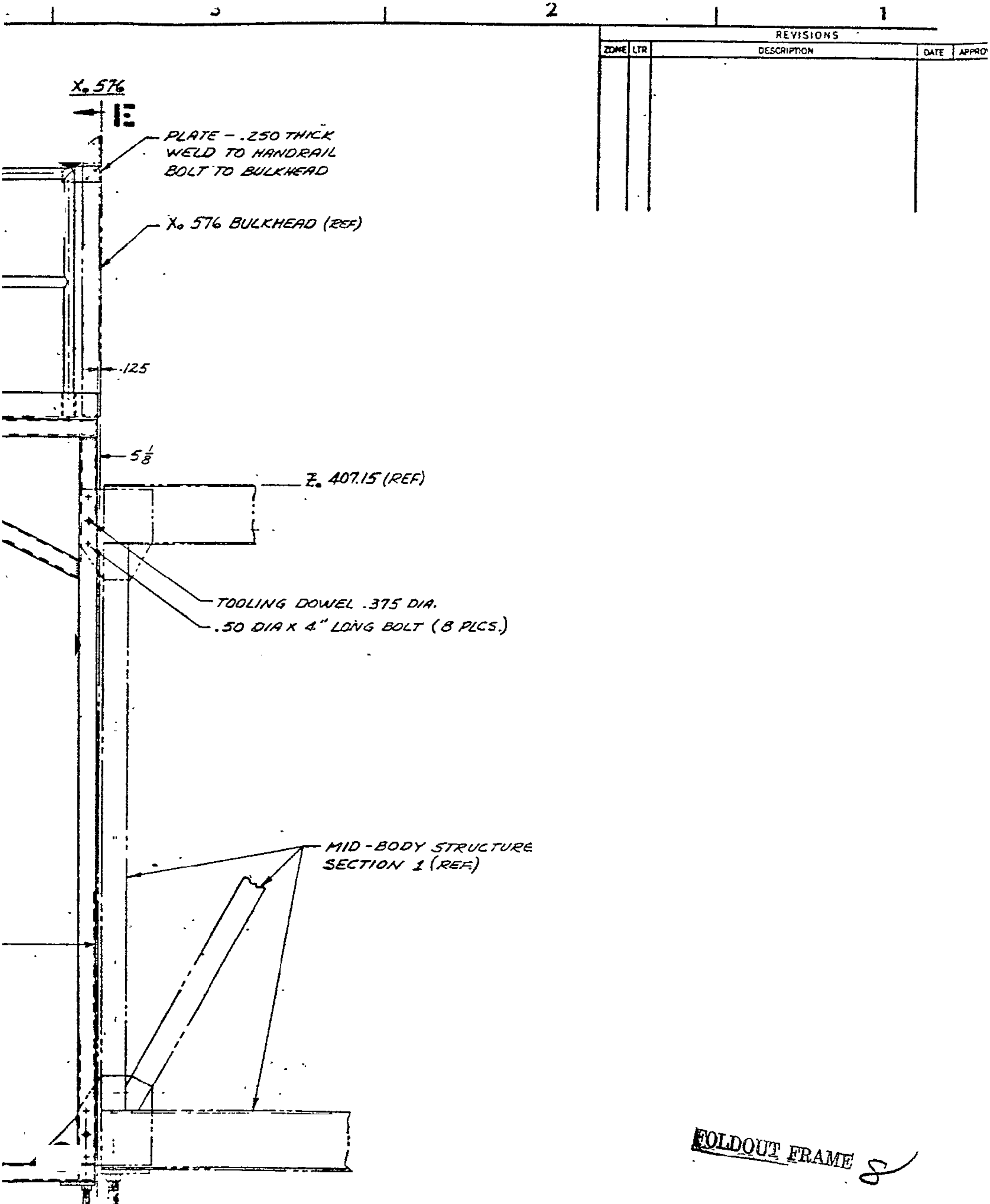
FOLDOUT FRAME 5



FOLDOUT FRAME 6

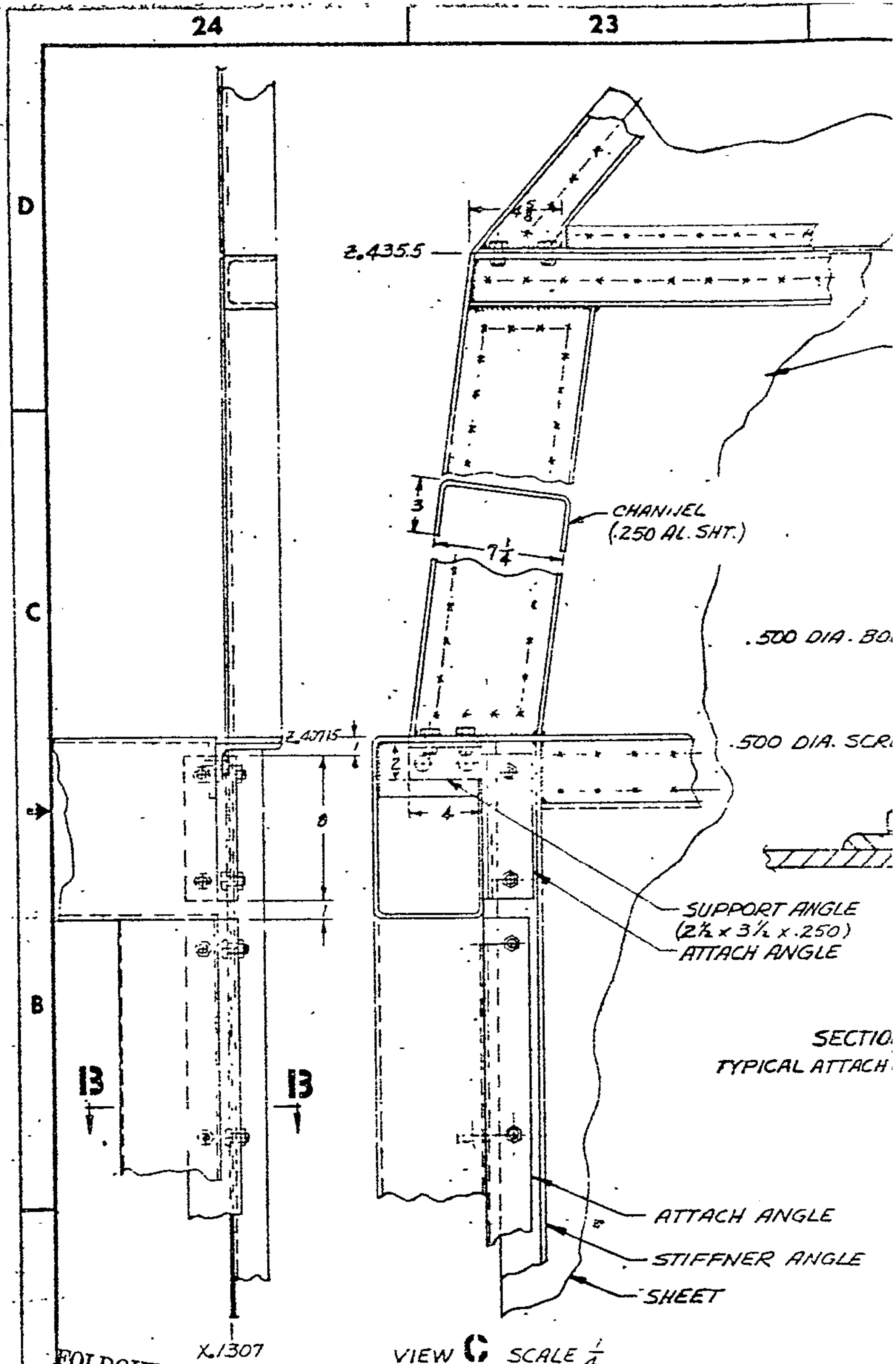


FOLDOUT FRAME

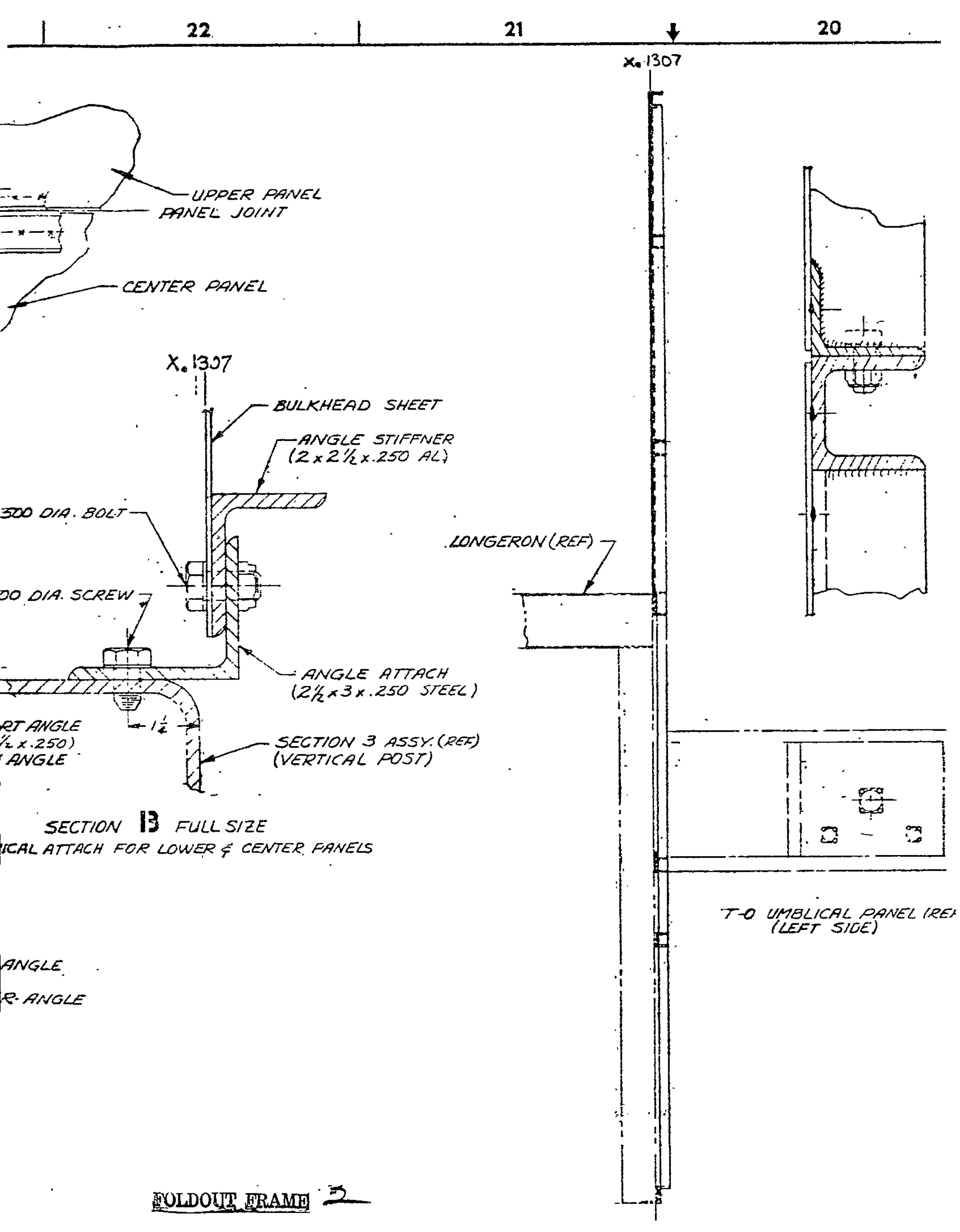


FOLDOUT FRAME 8

FIGURE 6-12 AFT FLIGHT DECK SUPPORT STRUCTURE ASSEMBLY

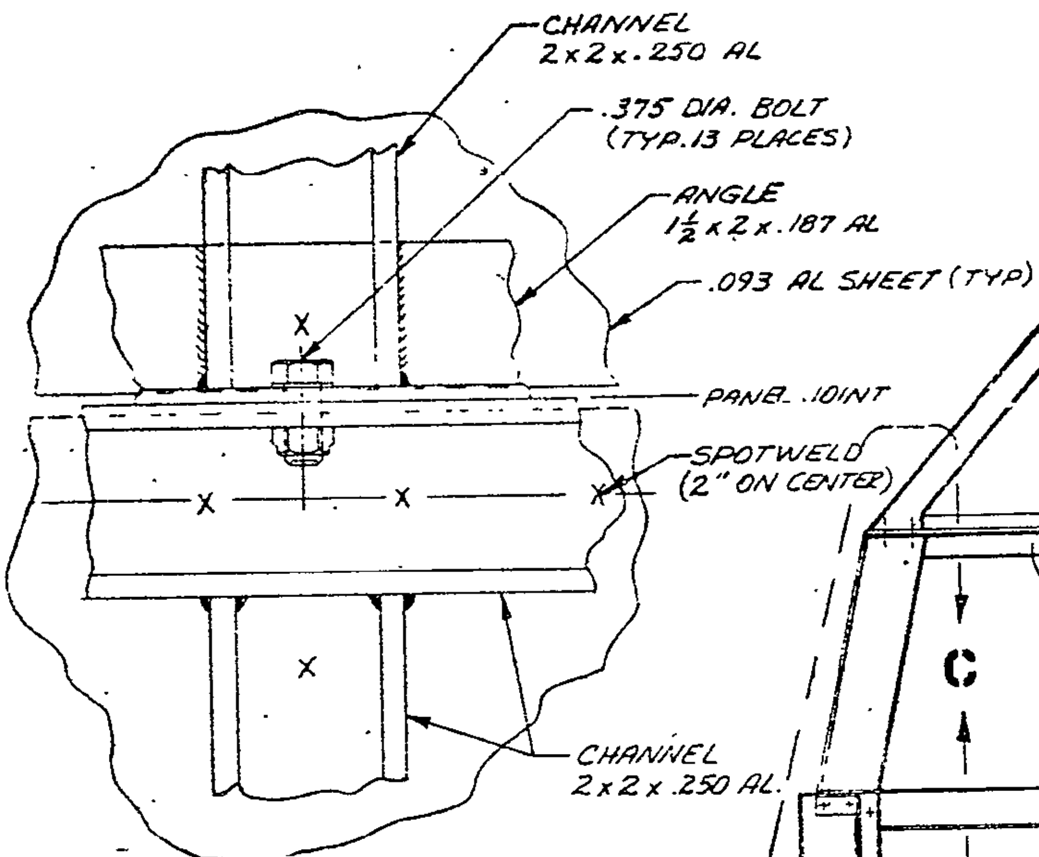


24
23
D
C
B
A
2.435.5
4 5/8
3
7 1/4
CHANNEL
(.250 AL. SHT.)
.500 DIA. BO
.500 DIA. SCR
2.407.15
8
2
4
SUPPORT ANGLE
(2 1/2 x 3 1/2 x .250)
ATTACH ANGLE
SECTIO
TYPICAL ATTACH
B
B
ATTACH ANGLE
STIFFNER ANGLE
SHEET
X.1307
VIEW C SCALE 1/4

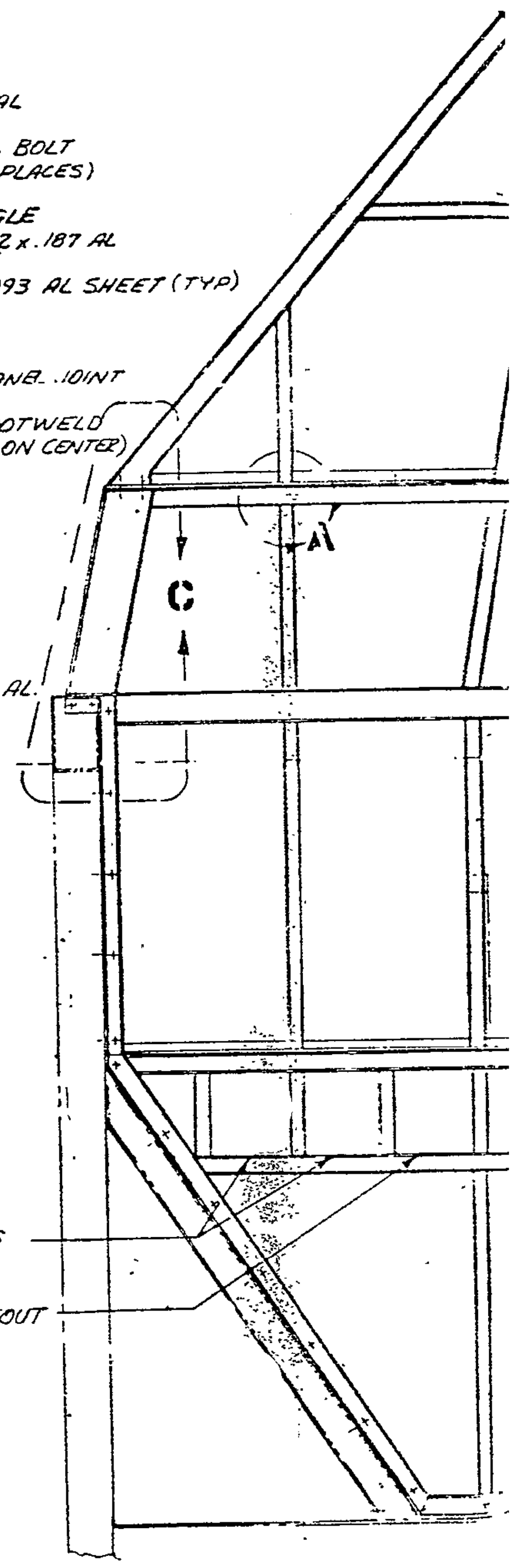


FOLDOUT FRAME 2

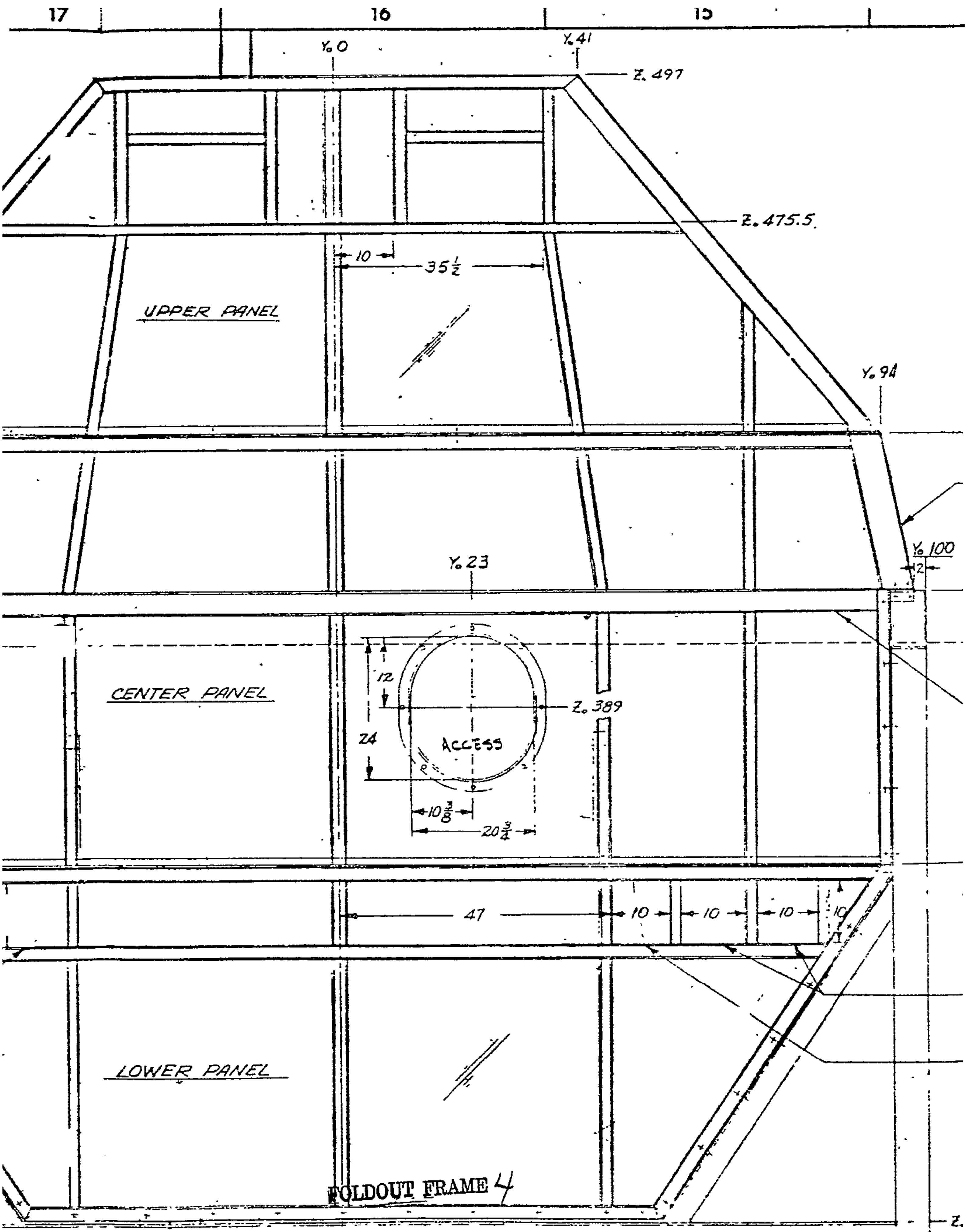
19 18 17



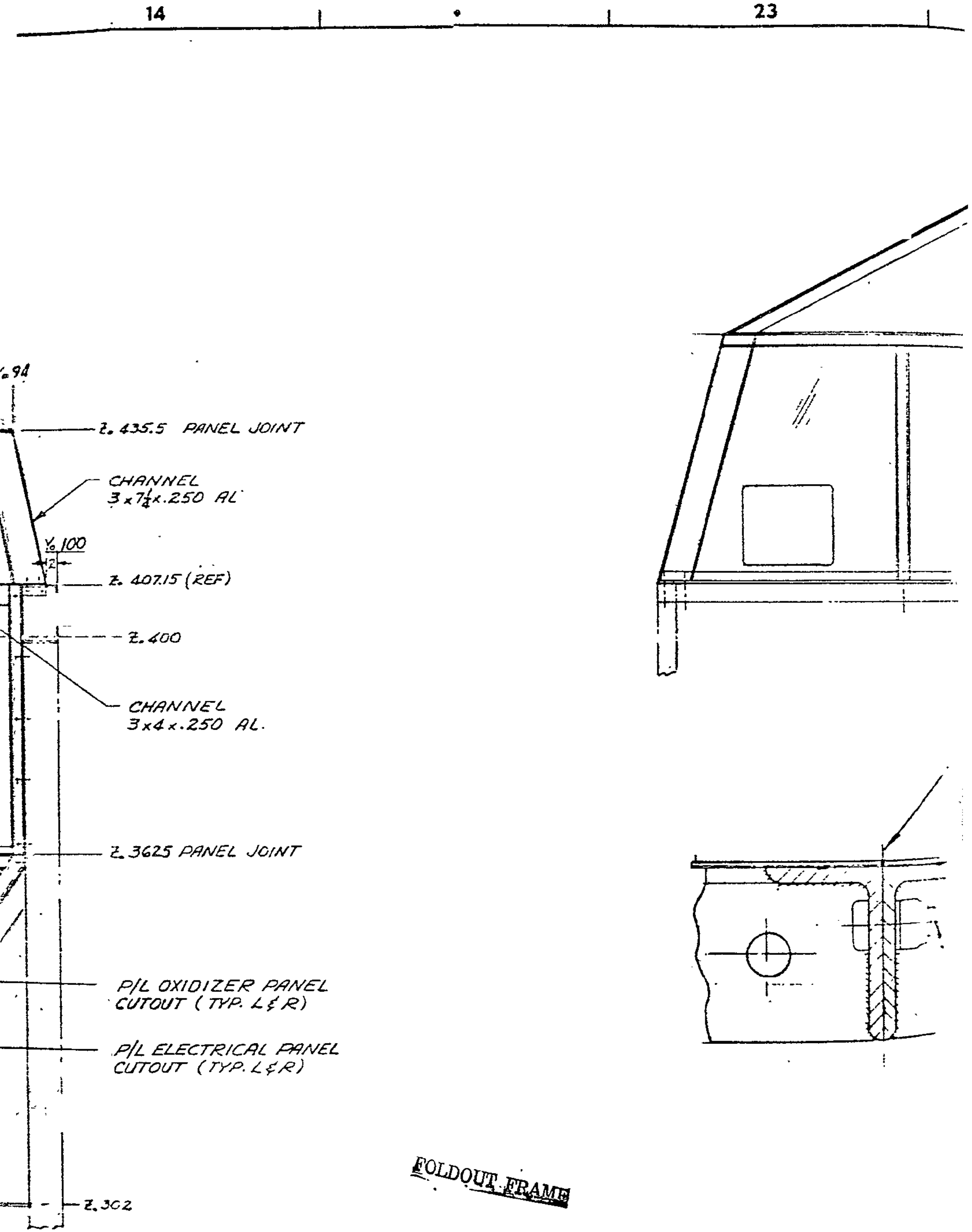
VIEW A FULL SIZE
TYPICAL ATTACH AT PANEL JOINTS



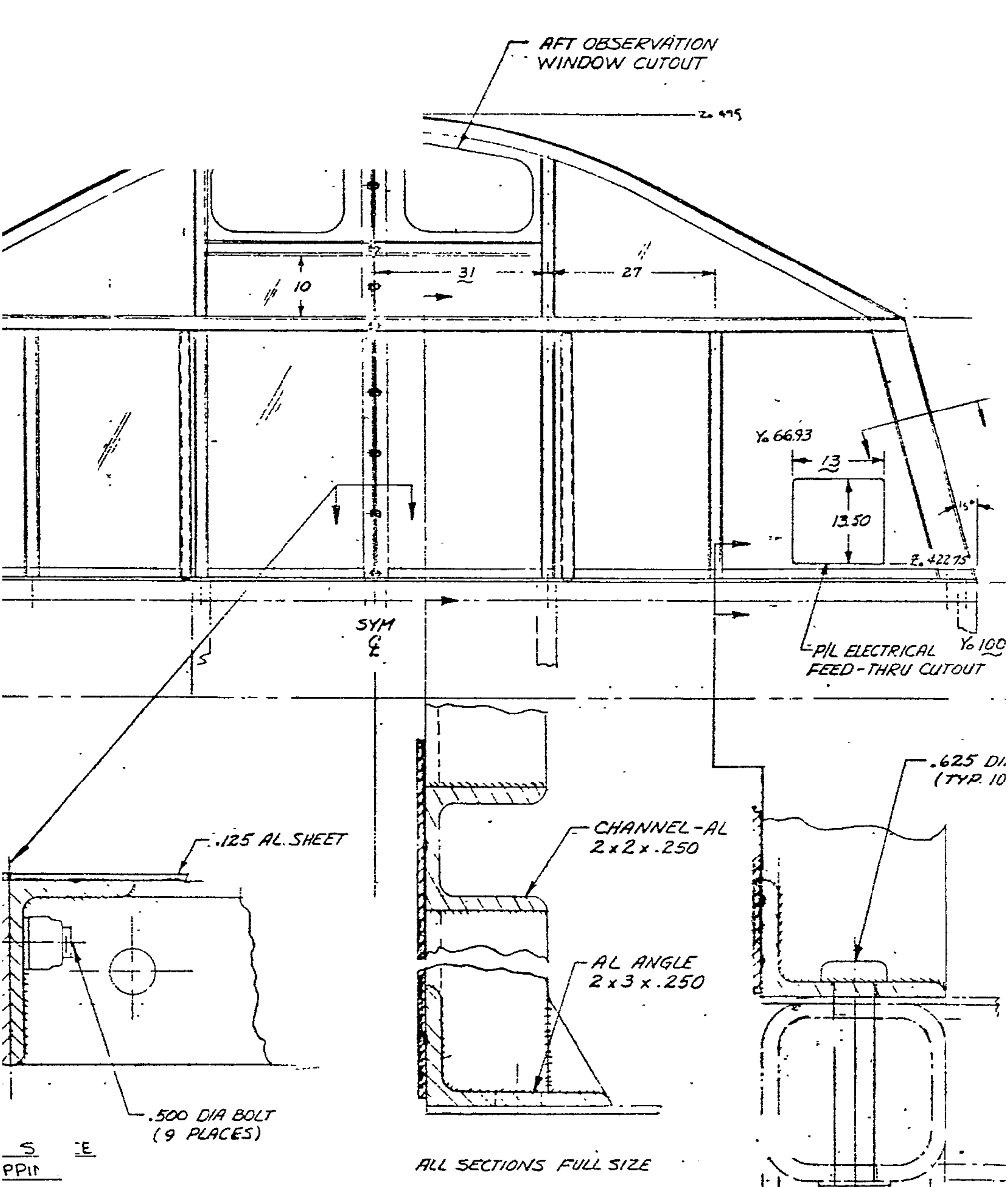
FOLDOUT FRAME 3



$X_0$1307 BULKHEAD - LOOKING FORWARD

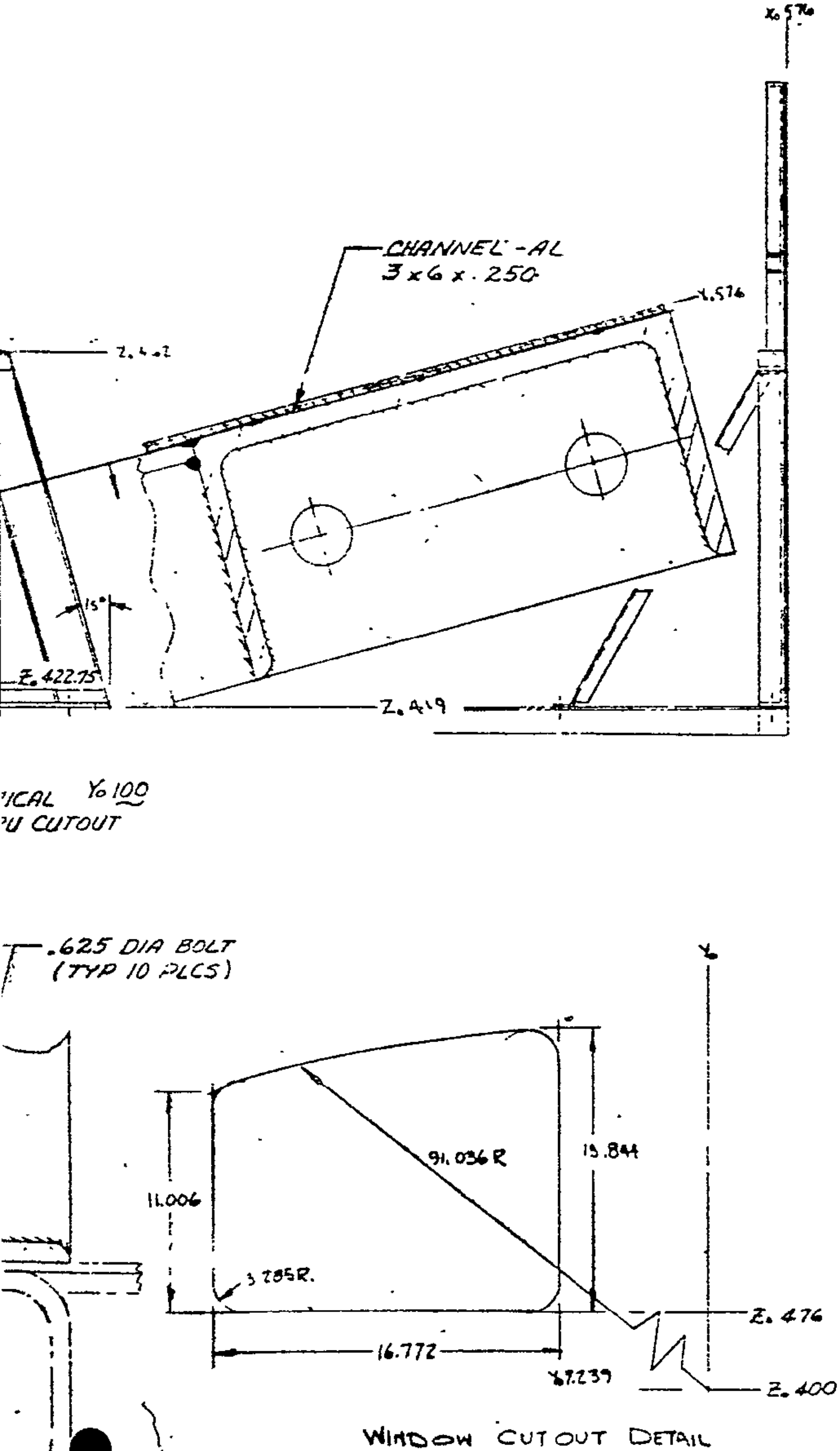

14
23
Z. 435.5 PANEL JOINT
CHANNEL
3 x 7½ x .250 AL
Z. 407.15 (REF)
Z. 400
CHANNEL
3 x 4 x .250 AL.
Z. 3625 PANEL JOINT
P/L OXIDIZER PANEL
CUTOUT (TYP. L & R)
P/L ELECTRICAL PANEL
CUTOUT (TYP. L & R)
Z. 302

22 21 20



$X_0$576 BULKHEAD - LOOKING AFT

FOLDOUT FRAME 6



FOLDOUT FRAME

FIGURE 6-13 $X_0$576 AND $X_0$1307 BULKHEAD STRUCTURE ASSEMBLY

An illustration of the non-deployable bridge fitting is shown in Figure 6-14. A tee slot interface between the journal fitting and the bridge rail provides a positive means of attachment and allows the journal to be positioned at any permissable payload attach station location. Two shear pins incorporated in the lower section of the journal fitting engage holes in the top of bridge rail to lock the journal fitting in postion. Available primary trunnion X_O station locations are presented in Table 6.2.

6.2.2.5 Auxiliary Keel Fitting

A machined part as shown in Figure 6-15 is used for the payload keel retention. The fitting machined I/F simulates the Orbiter flight hardware I/F. The fitting may be clamped or may be bolted at pre-indexed X_O locations to two zee extrusions which run the entire length of the mid-body, fastened in-turn to the keel beam (Figure 6-7). Available keel retention X_O locations are presented in Table 6.2.

6.2.2.6 Electrical and Fluid Interfaces

Details of the electrical and fluid interfaces for the payload are shown in Figure 6-16. Service panels on the X_O576 and X_O1307 bulkhead, wire tray, primary and secondary power I/F, and payload heat exchanger I/F are described. Additonal information and details of the elements comprising the standard IVE and the optional equipment are provided in Vol. II Appendix A Hardware Utilization List (HUL) and in Vol. III Horizontal IVE Specification Data, Section 7.0.

6.3 HORIZONTAL IVE ELECTRICAL SUBSYSTEM

The Horizontal IVE electrical subsystem (Figure 6-4) consists of the following elements:

1. Operators Console - Space Division designed control and monitor electronics. Includes controller/central processor unit (C/CPU with peripherals, man/machine interface elements and test measurement equipment (wide band recorder and signal measurement devices.)

2. Aft Flight Deck Set - Simulation of aft crew cabin

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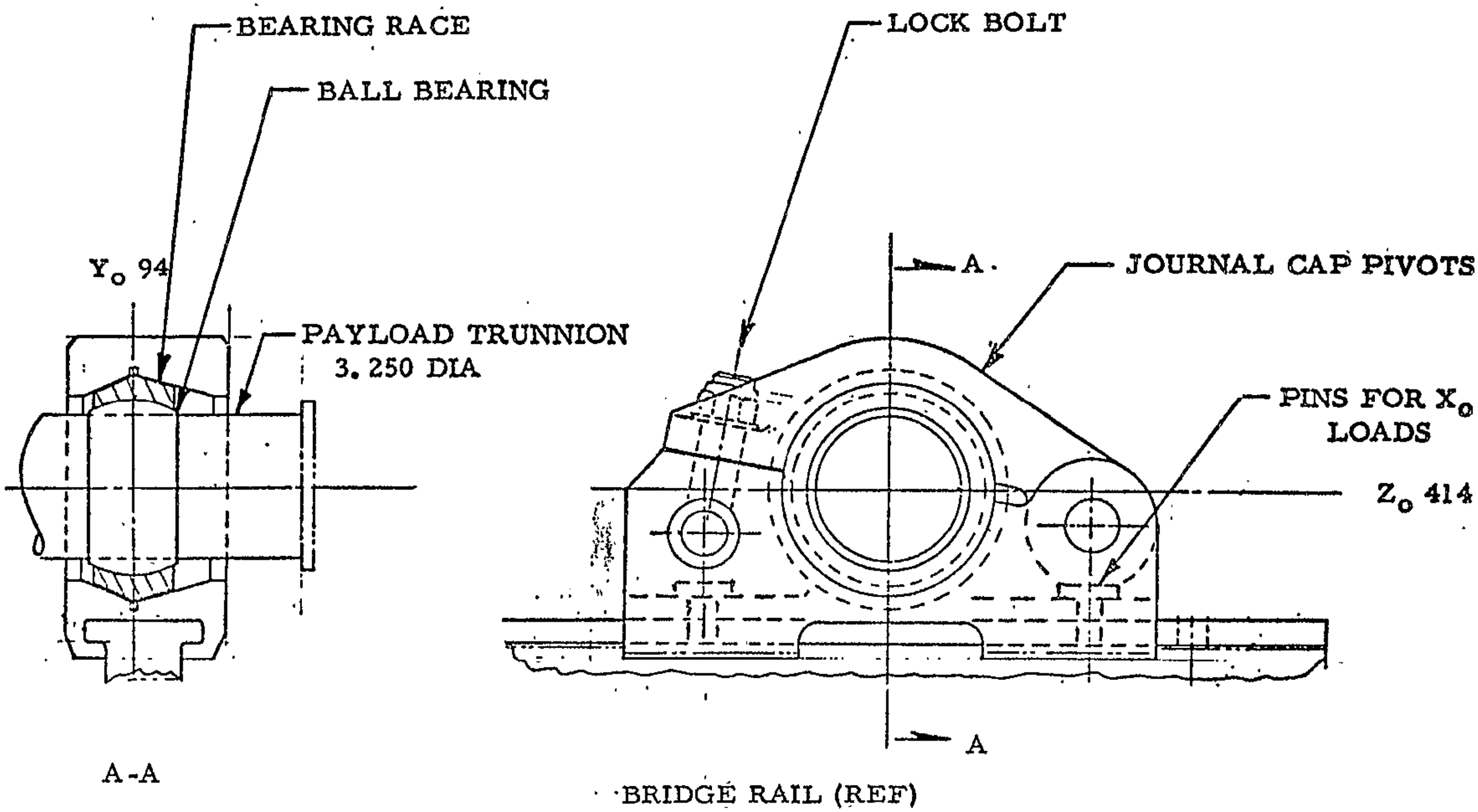

FIGURE 6-14 PRIMARY LONGERON FITTING - NONDEPLOYABLE

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Table 6.2 Payload Attach Points - Longeron and Keel
Xo Locations - Inches (mm)

Longeron Zo 414.0 (10515.6); Yo ± 94.0 (2387.6); Keel Zo 305.0 (7747) Except as noted:

Attach Pt #	Inches	mm	Attach Pt #	Inches	mm	Attach Pt #	Inches	mm	Attach Pt #	Inches	mm
155	612.73	(15563.4)	207	817.27	(20758.6)	246	970.67	(24654.9)	286	1128.00	(28651.2)
156	616.67	(15663.3)	208	821.20	(20858.5)	247L	974.60	(24754.8)	287	1131.93	(28751.1)
157	619.00	(15722.6)	209	825.13	(20958.4)	251	990.33	(25154.5)	288L	1135.87	(28851.0)
158	624.53	(15863.1)	210	829.07	(21058.3)	252	994.27	(25254.4)	289L	1139.80	(28950.9)
159	628.47	(15963.1)	211	833.00	(21158.2)	253	998.20	(25354.3)	292K	1151.60	(29250.6)
160	632.40	(16063.0)	212	836.93	(21258.1)	254	1002.13	(25454.2)	293K	1155.53	(29350.5)
164	649.00	(16484.6)	213	840.87	(21358.0)	255	1006.07	(25554.1)	294K	1159.47	(29450.5)
165	652.07	(16562.5)	214	844.80	(21457.9)	256	1010.00	(25654.0)	295K	1163.40	(29550.4)
166	656.00	(16662.4)	215	848.73	(21557.8)	257	1013.93	(25753.9)	296	1167.33	(29650.3)
167	659.93	(16762.3)	216	852.67	(21657.7)	258	1017.87	(25853.8)	297	1171.27	(29750.2)
177	699.27	(17761.4)	217	856.60	(21757.6)	259	1021.80	(25953.7)	298	1175.20	(29850.1)
178	703.20	(17861.3)	221L	872.33	(22157.3)	260	1025.73	(26053.6)	299	1179.13	(29950.0)
179	707.13	(17961.2)	222	876.27	(22257.2)	261	1029.67	(26153.5)	300K	1181.00	(29997.4)
180	711.07	(18061.1)	223	880.20	(22357.1)	262	1033.60	(26253.4)	300L	1183.07	(30049.9)
181	715.00	(18161.0)	224	884.13	(22457.0)	266L	1049.33	(26653.1)			
182	718.93	(18260.9)	225	888.07	(22556.9)	267	1053.27	(26753.0)	304L	1198.80	(30449.5)
183	722.87	(18360.8)	226	892.00	(22656.8)	268	1057.20	(26852.9)	*305	1202.73	(30549.4)
184	726.80	(18460.7)	227	895.93	(22756.7)	269	1061.13	(26952.8)	*306	1206.67	(30649.3)
185	730.73	(18560.6)	228	899.87	(22856.6)	270	1065.07	(27052.7)	*307	1210.60	(30749.2)
186	734.67	(18660.5)	229K	903.80	(22956.5)	271	1069.00	(27152.6)	*308	1214.53	(30849.1)
187K	738.60	(18760.4)	230K	907.73	(23056.4)	272	1072.93	(27252.5)	*309	1218.47	(30949.1)
188	742.53	(18860.3)	231K	911.67	(23156.3)	273	1076.87	(27352.4)	*310	1222.40	(31049.0)
192L	758.27	(19260.0)	234L	923.47	(23456.0)	274	1080.80	(27452.3)	*311	1226.33	(31148.9)
193	762.20	(19359.0)	235L	927.40	(23556.0)	275L	1084.73	(27552.2)	*312	1230.27	(31248.8)
194	766.13	(19459.8)	236	931.33	(23655.9)	276L	1088.67	(27652.1)	313L	1234.20	(31348.7)
195	770.07	(19559.7)	237	935.27	(23755.8)	277L	1092.60	(27752.0)	314L	1238.13	(31448.6)
196	774.00	(19659.6)	238	939.20	(23855.7)	279K	1100.47	(27951.9)	315L	1242.07	(31548.5)
197	777.93	(19759.5)	239	943.13	(23955.6)	280K	1104.40	(28051.8)	316L	1246.00	(31648.4)
198	781.87	(19859.4)	240	947.07	(24055.5)	281	1108.33	(28151.7)	*317K	1249.00	(31724.6)
199	785.80	(19959.3)	241	951.00	(24155.4)	282	1112.27	(28251.6)	322L	1269.60	(32247.8)
200	789.73	(20059.2)	242	954.93	(24255.3)	283	1116.20	(28351.5)	323L	1273.53	(32347.7)
201	793.67	(20159.1)	243	958.87	(24355.2)	284	1120.13	(28451.4)	324L	1277.47	(32447.6)
202	797.60	(20259.0)	244	962.80	(24455.1)	285	1124.07	(28551.3)	325L	1281.40	(32547.6)
203L	801.53	(20358.9)	245K	966.73	(24555.0)				**330L	1303.00	(33096.2)

NOTES: All attach points normally available are included in this list.
Attach points designated 'L' (e.g. number 192L) are available only at the longerons.
Attach points designated 'K' (e.g. number 295K) are available only at the keel.
*Zo 308.4 (7833.4) for Keel points 305K through 312K and 317K
**Zo 409 (10388.6), Yo 91.4 (2321.6) for 330L

DATA: JSC 07700 VOL XIV
CHG 15

Rockwell International
Space Division

TABLE 6.2 PAYLOAD ATTACH POINTS (CONT'D)

Additional Payload Attach Points Which Can Be Made Available On the Longerons
Xo Locations - Inches (mm)

Condition	Attach Pt #	Inches	mm	Attach Pt #	Inches	mm
Available When Manipulator Not Installed	168	663.86	(16862.2)	293L	1155.53	(29350.5)
	169	667.80	(16962.1)	294L	1159.47	(29450.4)
	170	671.73	(17062.0)	295L	1163.40	(29550.4)
	171	675.67	(17162.0)	317L	1249.93	(31748.3)
	172	679.60	(17261.9)	318L	1253.87	(31848.2)
	173	683.53	(17361.8)	319L	1257.80	(31948.1)
	230L	907.73	(23056.4)			
Available With Special Longeron Bridges	189L	746.47	(18960.3)	250L	986.40	(25054.6)
	190L	750.40	(19060.2)	263L	1037.53	(26353.3)
	191L	754.33	(19160.1)	264L	1041.47	(26453.3)
	204L	805.47	(20458.9)	265L	1045.40	(26553.2)
	205L	809.40	(20558.8)	278L	1096.53	(27851.9)
	206L	813.33	(20658.7)	279	1100.47	(27951.9)
	218L	860.53	(21857.5)	280	1104.40	(28051.8)
	219L	864.47	(21957.4)	301L	1187.00	(30149.8)
	220L	868.40	(22057.4)	302L	1190.93	(30249.7)
	248L	978.53	(24854.7)	303L	1194.87	(30349.6)
	249L	982.47	(24954.7)			
Available With Special Longeron When Manipulator Not Installed	231L	911.67	(23156.3)	291L	1147.67	(29150.7)
	232L	915.60	(23256.2)	292L	1151.60	(29250.6)
	233L	919.53	(23356.1)			

Attach Points Which Can Accommodate Payload Deployment Mechanisms*

Attach Point Number

181	213	256	283
182	214	257	284
183	215	258	285
184	216	259	286
185	222	260	287
195	223	261	288L
196	224	267	304L
197	225	268	306
198	226	269	307
199	227	270	308
200	240	271	309
201	241	272	310
202	242	273	311
208	243	274	312
209	253	275	313L
210	254	276	314L
211	255	282	315L
212			316L

*The capability to deploy payloads from these attach points is based upon a preliminary design of the deployment mechanism.

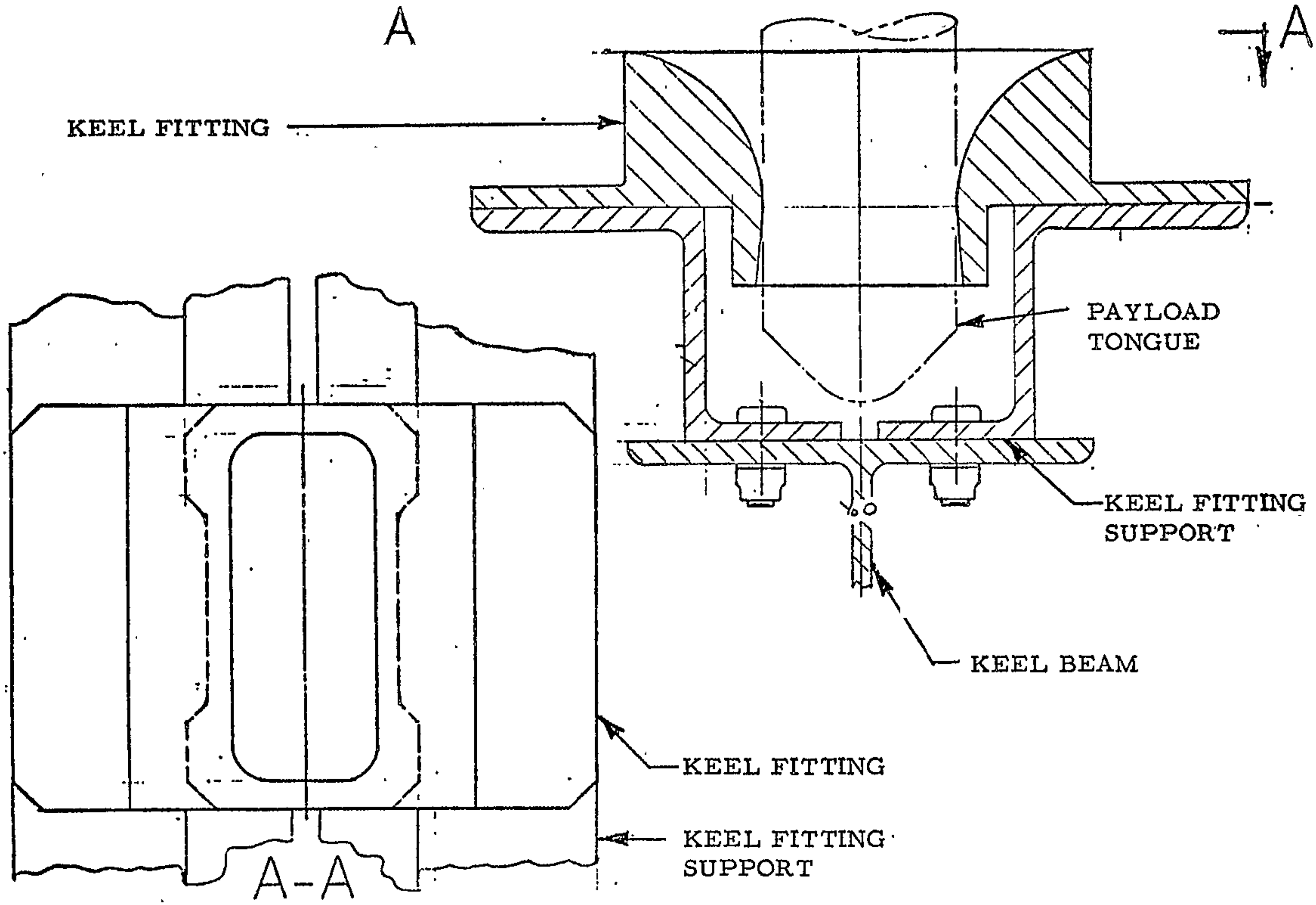
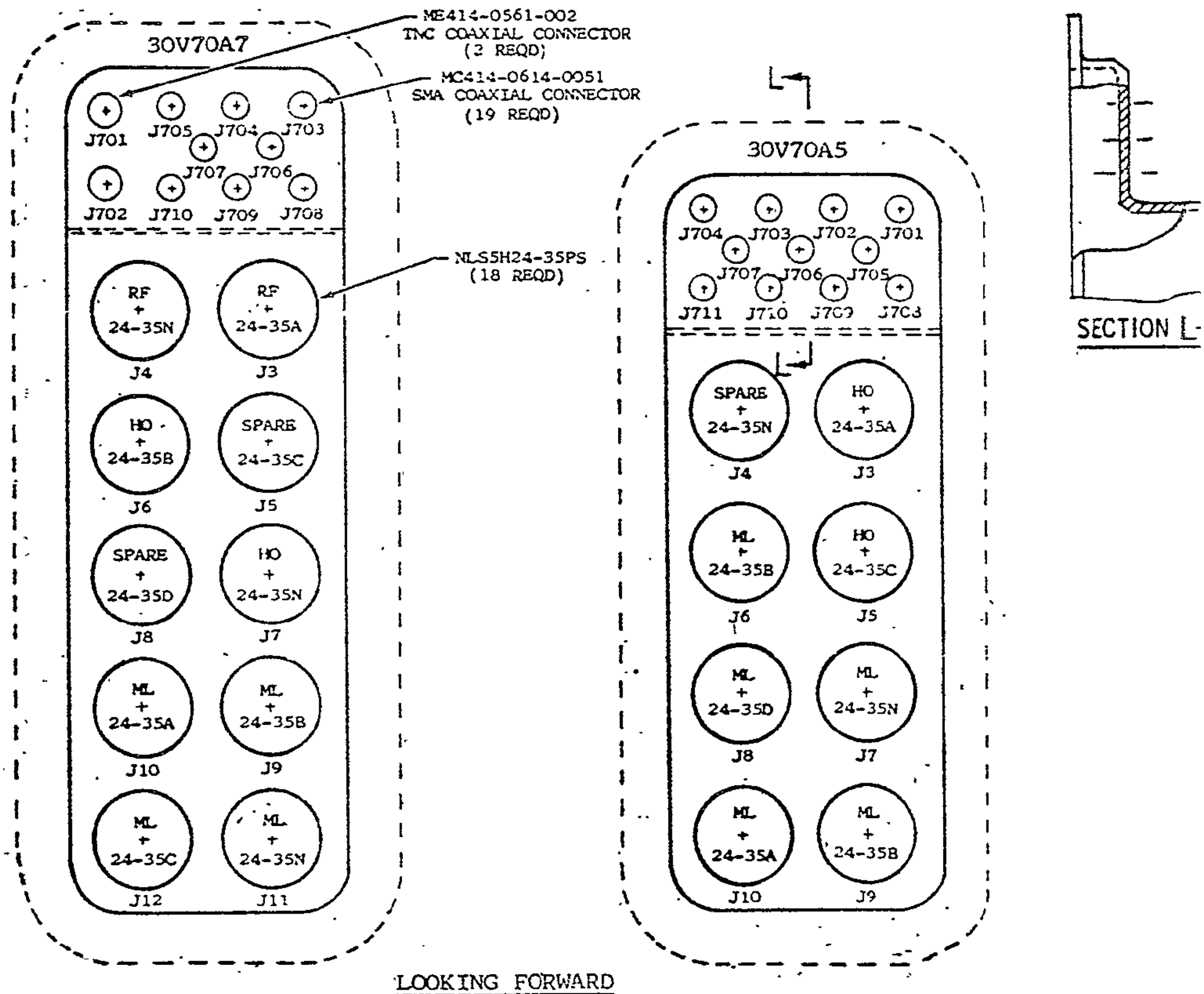
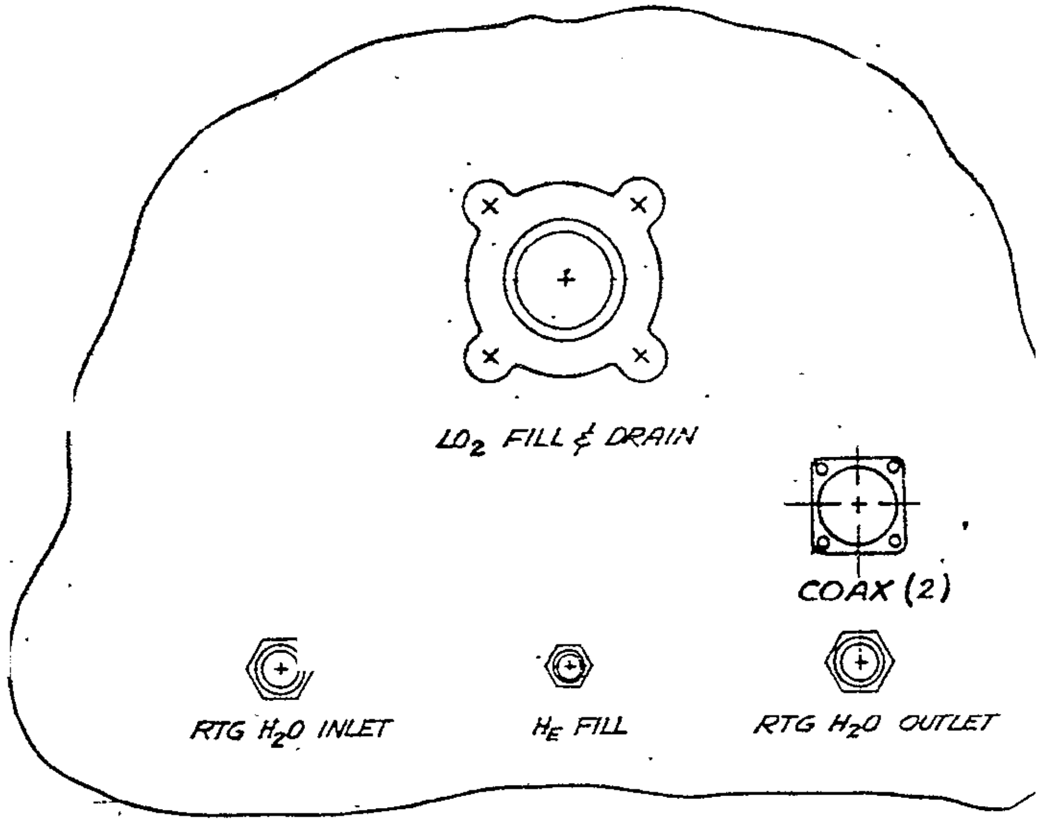


FIGURE 6-15 AUXILIARY KEEL FITTING

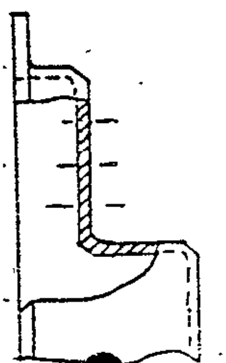


VIEW K-K

CONNECTOR CONFIGURATION

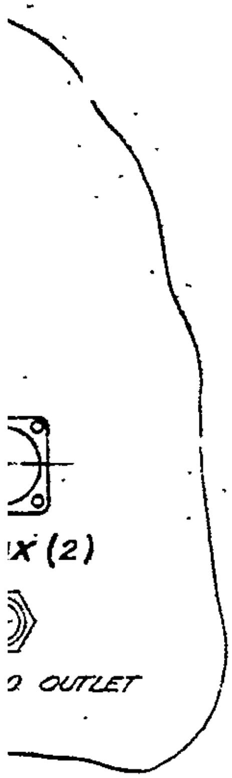


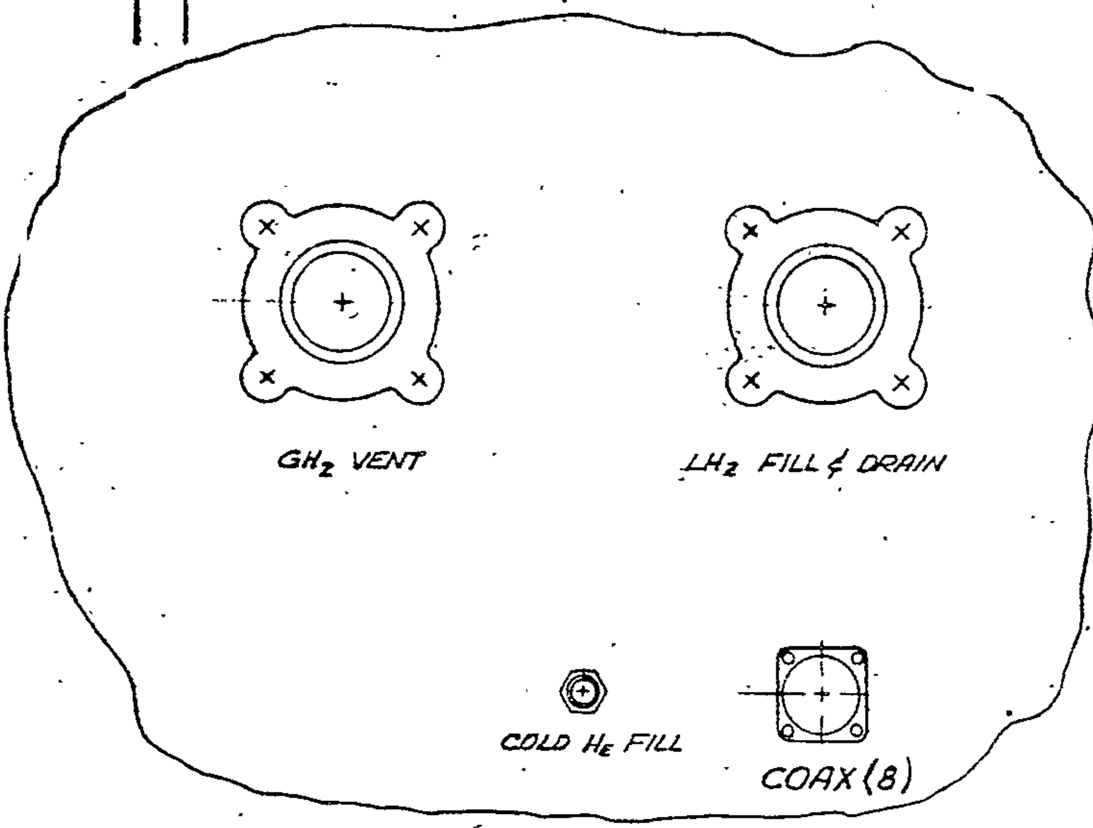
VIEW J SCALE $\frac{1}{2}$
T-0 UMBILICAL PANEL RIGHT SIDE



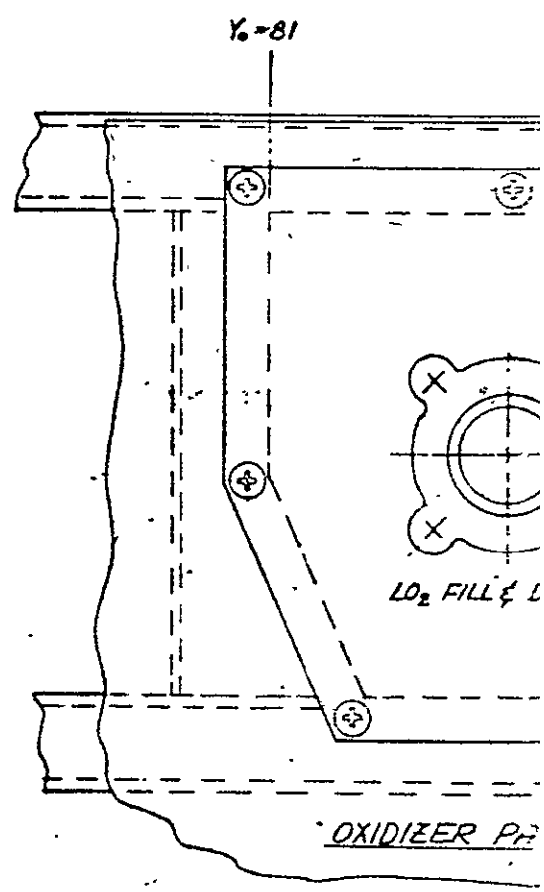
SECTION L-L

17 16 15

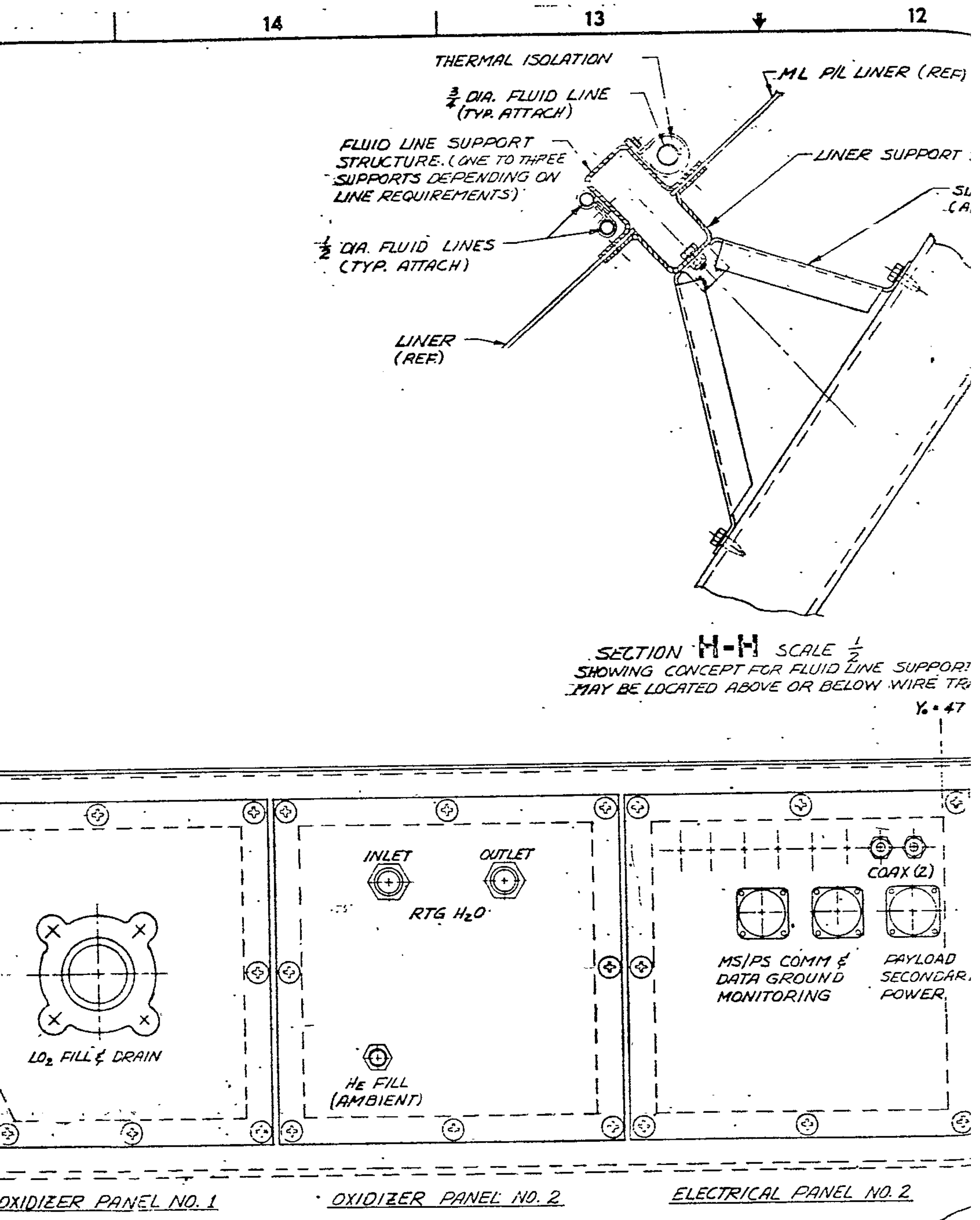




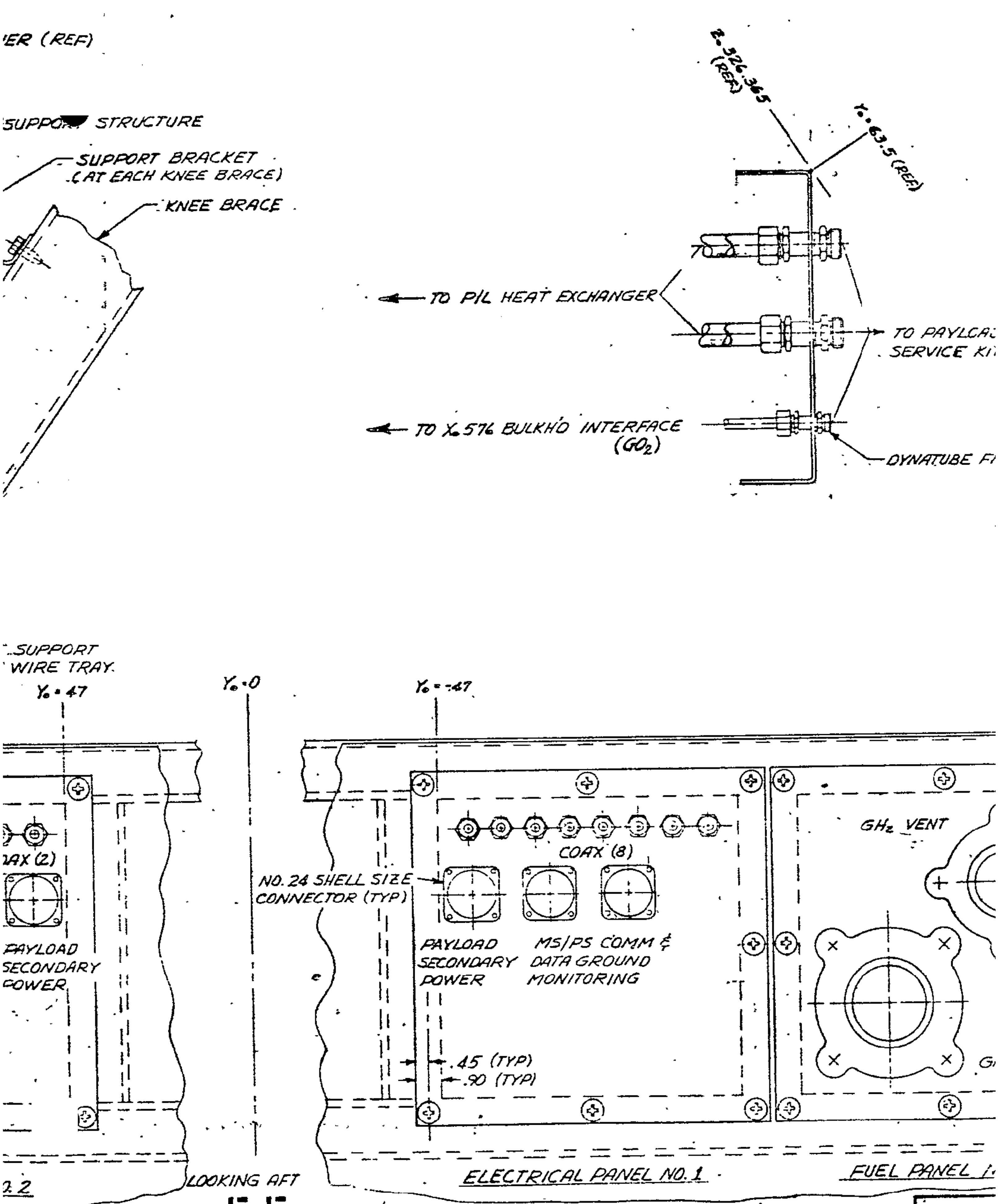
VIEW G SCALE $\frac{1}{2}$
T-0 UMBILICAL PANEL LEFT SIDE



FOLDOUT FRAME 3



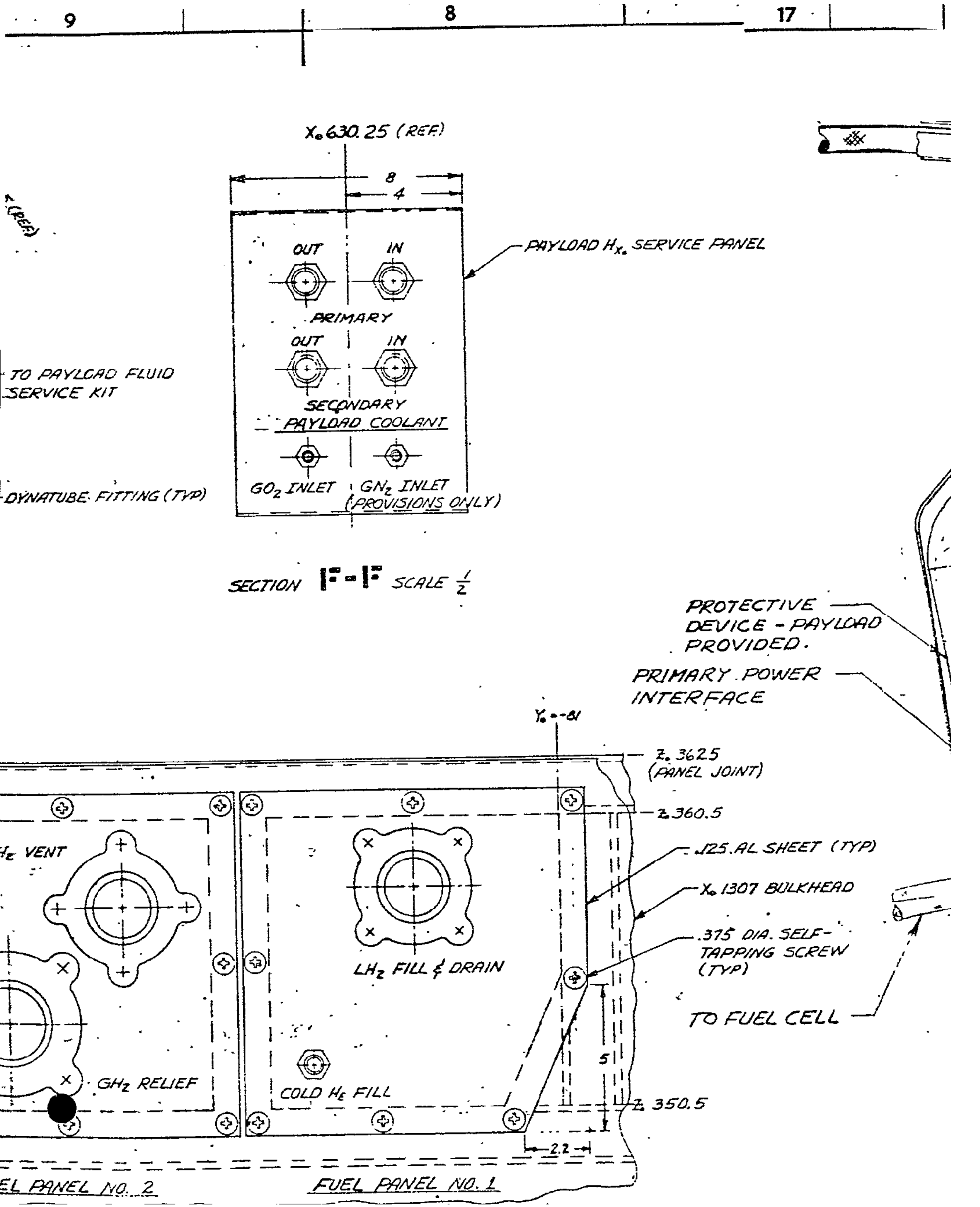
14
13
12
THERMAL ISOLATION
ML P/L LINER (REF)
$\frac{3}{4}$ DIA. FLUID LINE (TYP. ATTACH)
FLUID LINE SUPPORT STRUCTURE. (ONE TO THREE SUPPORTS DEPENDING ON LINE REQUIREMENTS)
LINER SUPPORT
$\frac{1}{2}$ DIA. FLUID LINES (TYP. ATTACH)
LINER (REF)
SECTION H-H SCALE $\frac{1}{2}$
SHOWING CONCEPT FOR FLUID LINE SUPPOR
MAY BE LOCATED ABOVE OR BELOW WIRE TR
Y_o = 47
LO_2 FILL & DRAIN
INLET
OUTLET
RTG H_2O
HE FILL (AMBIENT)
COAX (2)
MS/PS COMM & DATA GROUND MONITORING
PAYLOAD SECONDAR POWER
OXIDIZER PANEL NO. 1
OXIDIZER PANEL NO. 2
ELECTRICAL PANEL NO. 2



VIEW E-E SCALE $\frac{1}{2}$

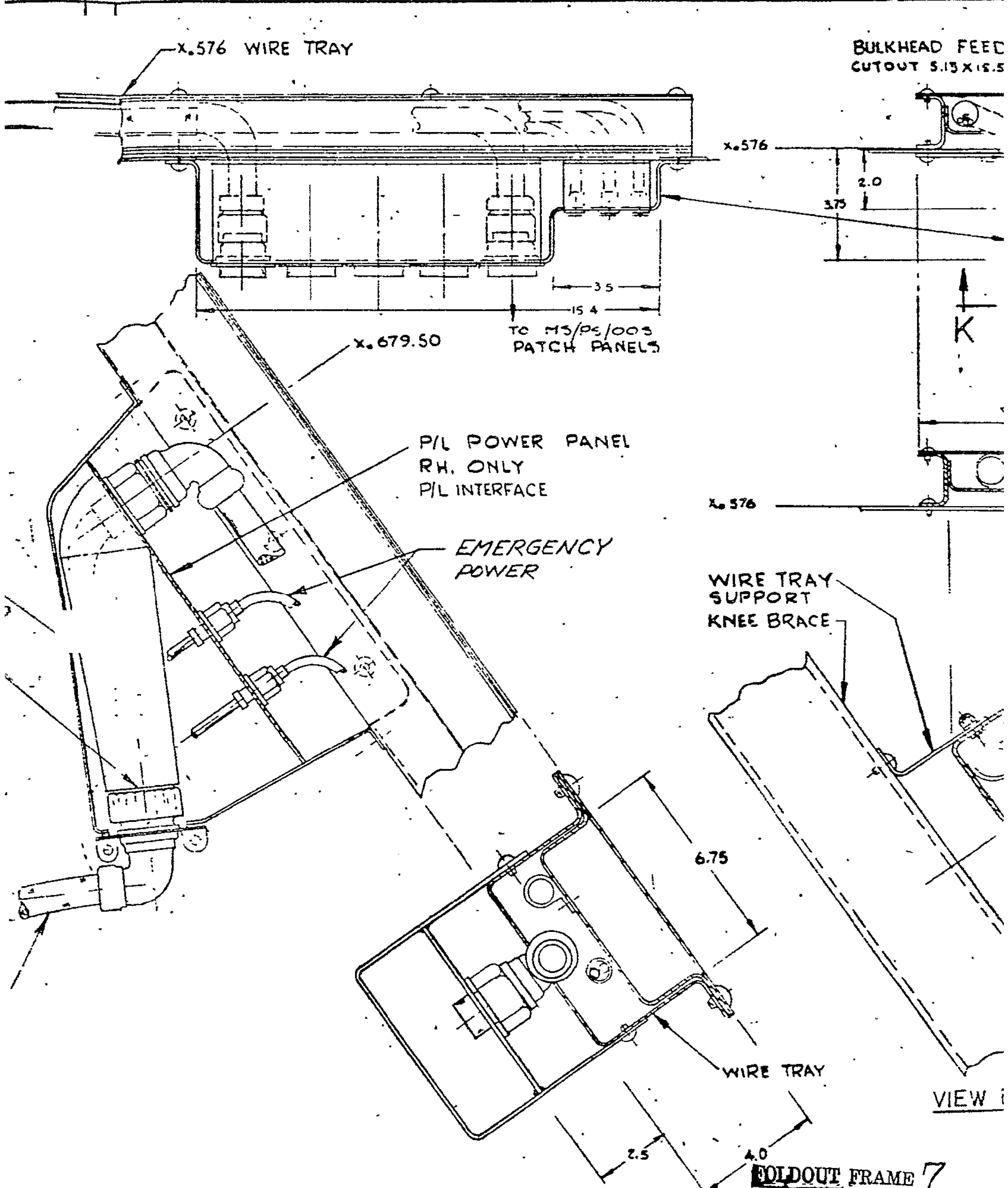
ALL CONNECTOR LOCATIONS ARE TB

FOLDOUT FRAME 5



9
8
17
X_o 630.25 (REF)
8
4
PAYLOAD H_{X_o} SERVICE PANEL
OUT
IN
PRIMARY
OUT
IN
TO PAYLOAD FLUID SERVICE KIT
SECONDARY
PAYLOAD COOLANT
DYNATUBE FITTING (TYP)
GO_2 INLET
GN_2 INLET (PROVISIONS ONLY)
SECTION F-F SCALE $\frac{1}{2}$
PROTECTIVE DEVICE - PAYLOAD PROVIDED.
PRIMARY POWER INTERFACE
Y_o = -81
Z_o 362.5 (PANEL JOINT)
Z_o 360.5
H_E VENT
.125 AL SHEET (TYP)
X_o 1307 BULKHEAD
.375 DIA. SELF-TAPPING SCREW (TYP)
LH_2 FILL & DRAIN
TO FUEL CELL
5
GH_2 RELIEF
COLD H_E FILL
Z_o 350.5
2.2
EL PANEL NO. 2
FUEL PANEL NO. 1

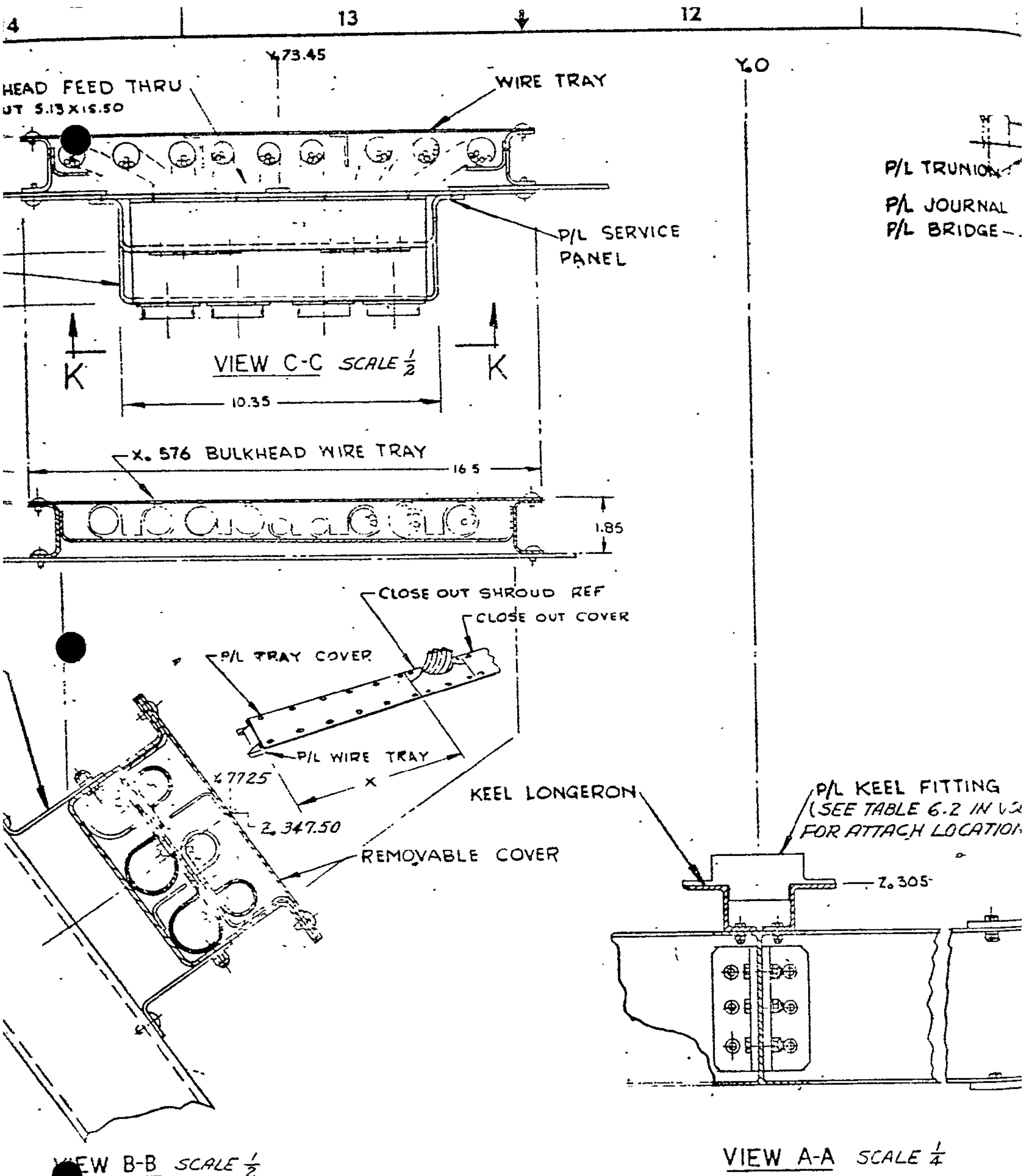
16 15 14



FOLDOUT FRAME 7

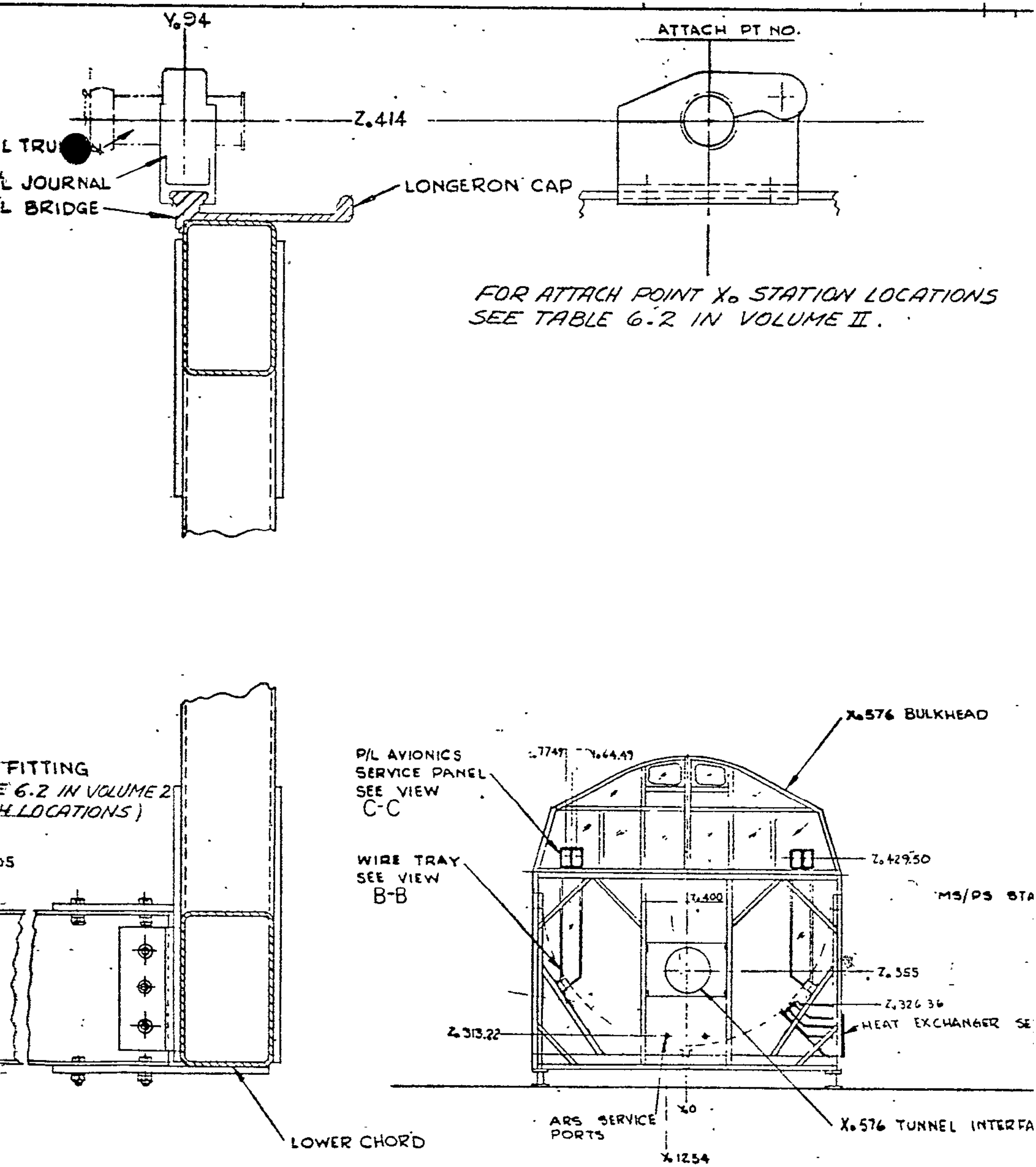
SECTION D-D SCALE $\frac{1}{2}$
STATION X_o 679.5 RIGHT SIDE ONLY

16 15 14



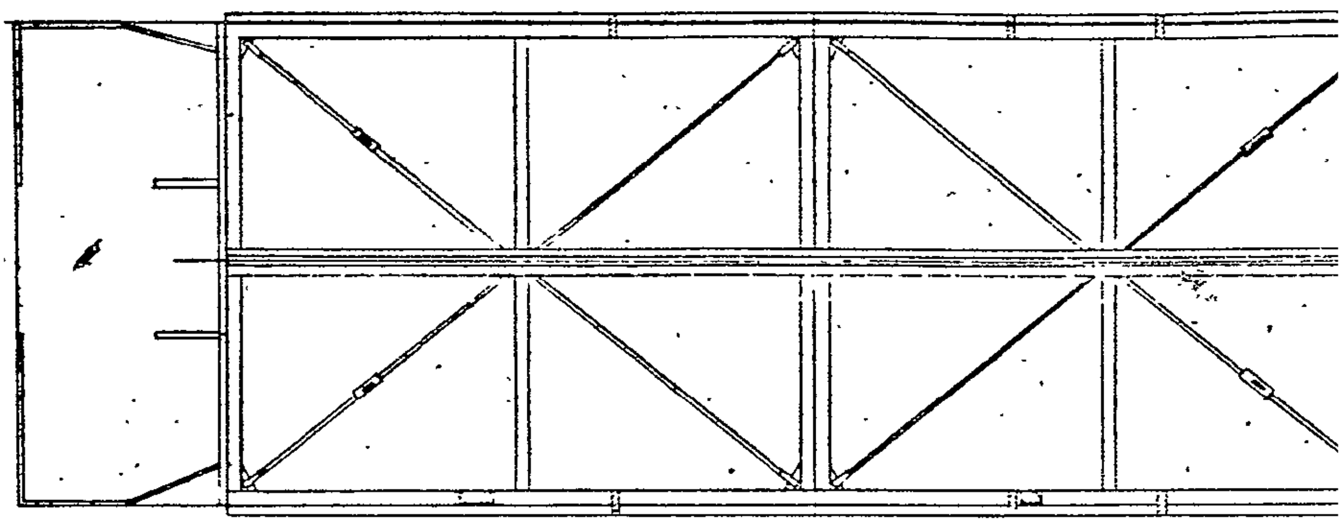
ME 7

FOLDOUT FRAME

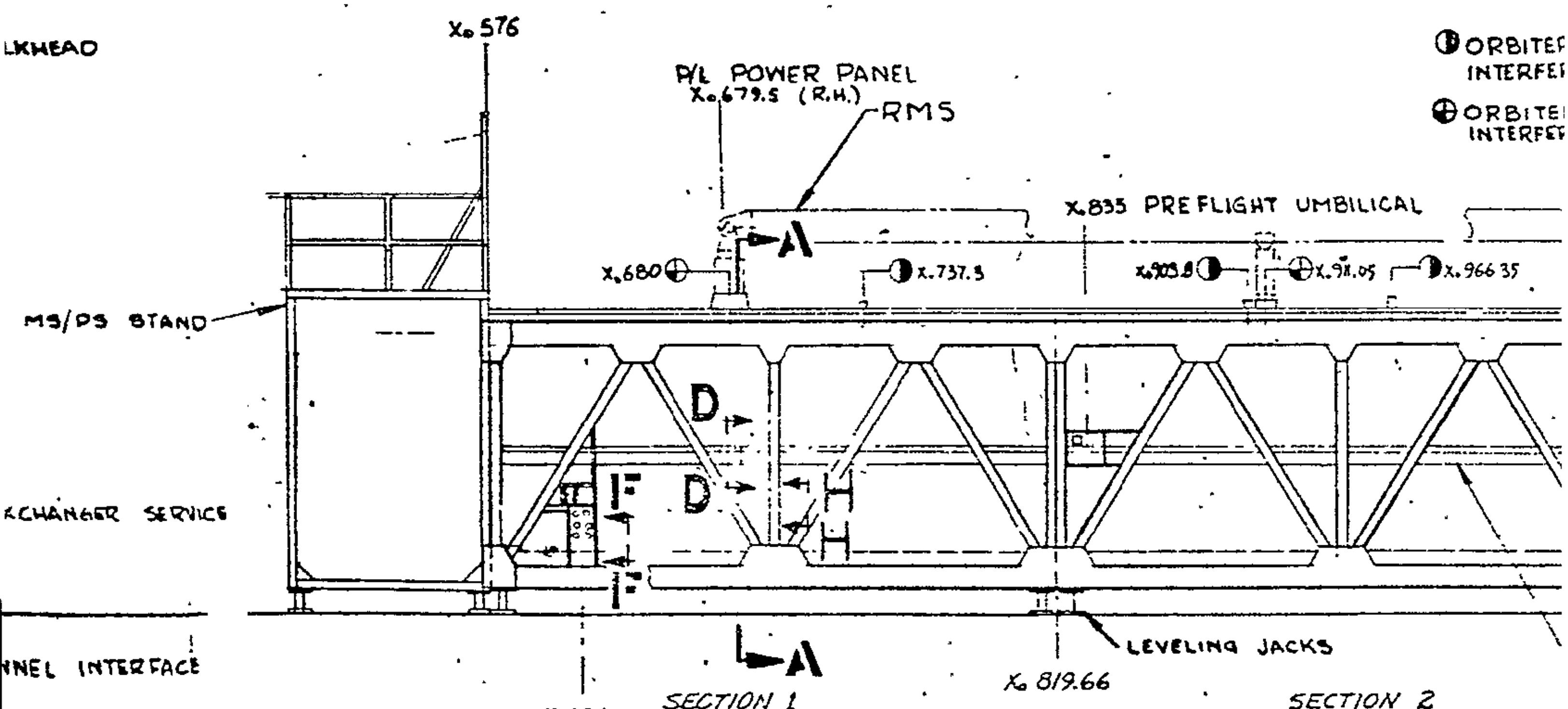

Y0 94
Z0 414
L TRU
L JOURNAL
L BRIDGE
LONGERON CAP
ATTACH PT NO.
FOR ATTACH POINT X0 STATION LOCATIONS
SEE TABLE 6.2 IN VOLUME II.
FITTING
E 6.2 IN VOLUME 2
4 LOCATIONS)
05
LOWER CHORD
X0 576 BULKHEAD
P/L AVIONICS
SERVICE PANEL
SEE VIEW
C-C
WIRE TRAY
SEE VIEW
B-B
Z0 429.50
Z0 400
MS/PS STA
Z0 355
Z0 326.36
HEAT EXCHANGER SE
Z0 313.22
ARS SERVICE
PORTS
X0
X0 1254
X0 576 TUNNEL INTERFA

OUT FRAME 8

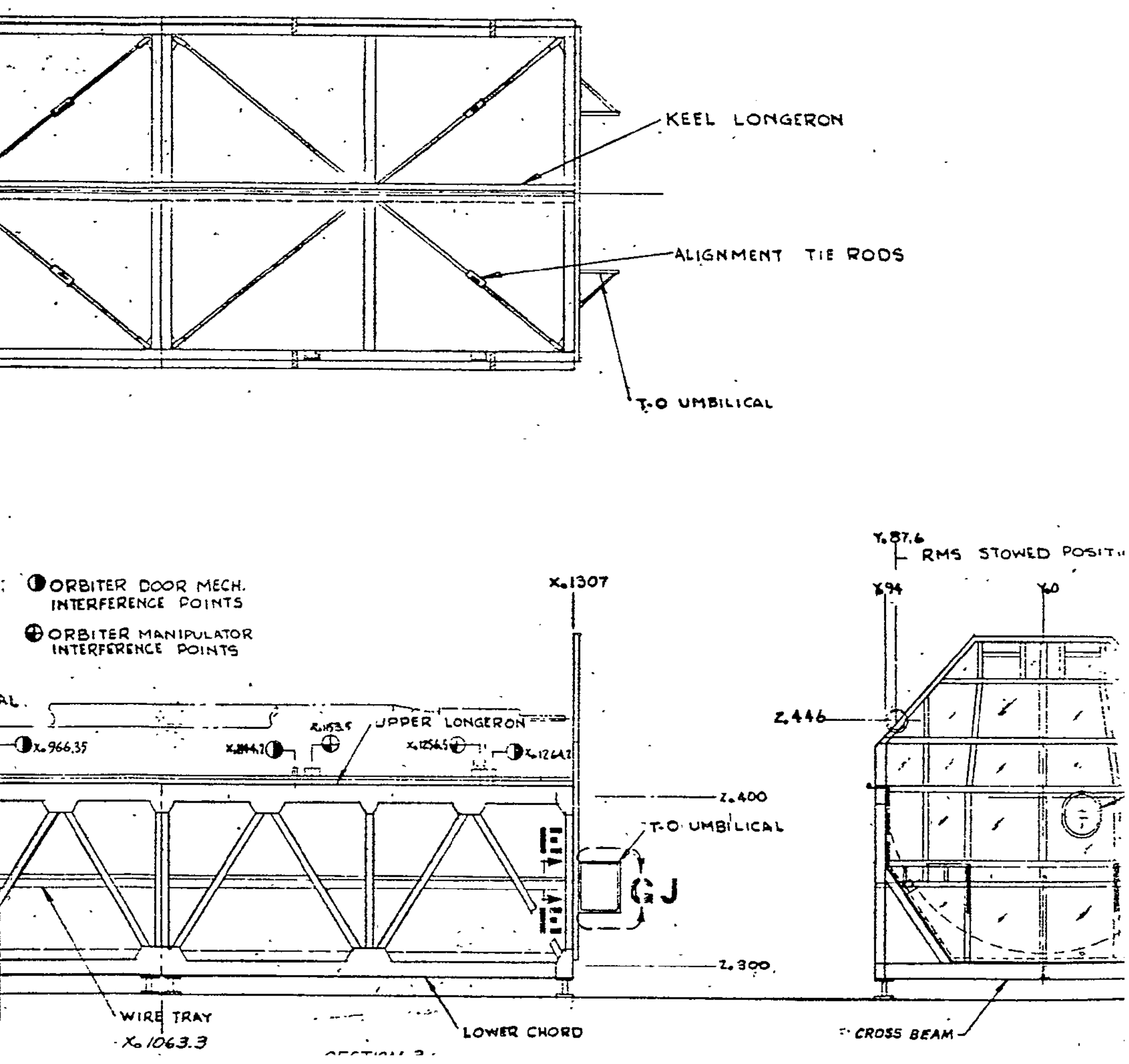
IONS



PLAN VIEW



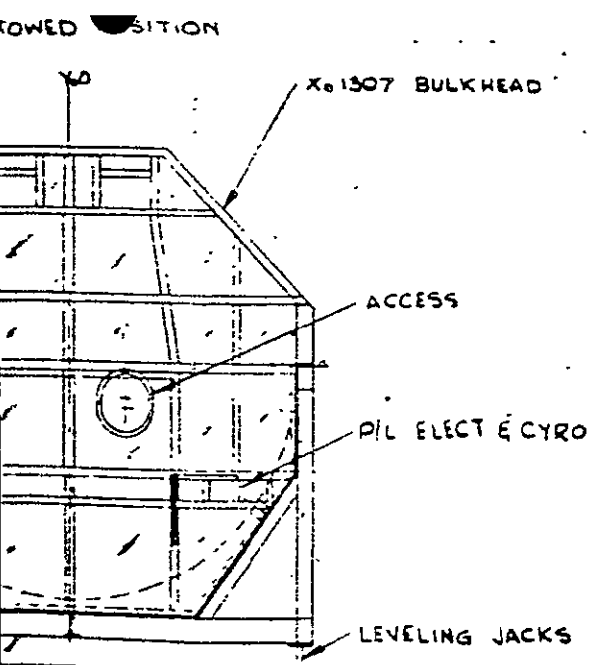
IVE. TRUSS STRUCTU



FOLDOUT FRAME 1D

	5	4	3

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



FOLDOUT FRAME

FIGURE 6-16 HORIZONTAL IVE PAYLOAD INTERFACES

with respect to payload operations. Includes mission station (MS), payload station (PS), on-orbit station (OOS), X_0576 electrical service panels, patch panels and wiring. Included in the PS, MS and OOS are all orbiter provide elements directly related to payload operations.

3. DC Power Set - DC power set which simulates the Orbiter fuel cell performance. Includes DC power supply, switching and distribution.

4. Software - An integrated set of software consisting of programming aids, test operations software, system support software and an operating system.

The basic design approach of the electrical subsystem was influenced by the desire to meet the performance requirements as dictated in Section 5.0 of this volume while providing maximum permissible design flexibility, cost effectiveness, reliable operation and growth. Key design features incorporated include:

1. Programmable patch panels for GSE thru-put.

2. Self-diagnostic measurements (readiness check and monitoring during operation).

3. Ease of special stimulus/monitor functions and fast reconfiguration through the patch panels.

4. Modular construction of the input/output I/O channels with similar characteristics.

5. Microprocessor technology to minimize the amount of new logic design and inherent increase in system flexibility.

6. Modularized software construction tailoring the operations to the needs of a specific payload user.

7. System expandability for inclusion of additional test units on an as needed basis (growth).

8. Growth provisions for use of additional C/CPU, wideband recorder, digital recorder and use of external (User) facility computer and uplink/downlink capability.

The following functions may be accomplished by the electrical subsystem:

A. Demonstrate Orbiter to Payload signal interface compatibility by simulating the Orbiter to payload interface. This includes:

   1. Static and dynamic signal characteristics

   2. Checks for correct signal interconnection

   3. Checks for cross-talk (shorts)

   4. Checks for out-of-tolerance conditions

   5. Test ability of payload to respond to Orbiter signals over the flight range of values.

B. Thruput digital command/data, discretes and analog signals from the payload to the payload support GSE. Since the nature and location of the GSE has not been specified, the line driver modules have not been included. Space for these modules has been included in the console. The switching is provided by means of programmable patch panels. Thus individual signals or groups of signals may be routed either to the IVE or GSE.

C. Provide encoded digital commands and discrete signals as required to the payload systems. These signals are provided through:

   1. MDM discrete output simulator

   2. MDM serial output simulator

   3. Uplink subsystem

      a. Ku-Band

      b. Payload Signal Processor (PSP)

   4. 28 bit SWS/SWM (Shuttle Data Bus Simulator)

D. Perform quantitative data processing of payload data:

   (1) Simulation of the Payload related data handling capabilities of the Orbiter Communications and

data handling (C&DH) system. This is accomplished with:

a. Patchable wide band recorder

b. Audio system

c. CCTV system

d. Ku-Band and FM signal processor simulation

(2) Perform functional testing of the payload (ie., command the payload and process/strip out the payload response data). This is accomplished by sending commands to the payload through:

a. Uplink simulator

b. Serial I/O simulator

c. Discrete safing commands

Monitoring can occur through:

a. MDM discrete I/O simulator

b. Serial I/O simulator

c. PDI/PSP simulator

d. C&W system

e. PCM - Master Unit Data Bus

f. Recording/post processing of data

Recording capacity provided allows for simultaneous recording of 14 tracks of data with a 2 MHz band width, at a recording speed of 120 IPS.

(3) Simulating the flight computer operating system (FCOS). This was accomplished from the standpoint of delivering commands and monitoring responses in the same sequence and time constraints which the payload would see in an Orbiter under flight conditions. In addition, there is planned capa-

bility for running payload applications which have been written in HAL or GOAL language during further system development stages.

(4) Simulating all payload related data readouts from the FCOS including interleaving of Orbiter and payload data. This is primarily a software function. The two major portions of hardware which support this are the digital tape unit and the PDI simulator. A journal tape of data readouts can be created on the digital tape unit. The PDI allows selection of the required payload data from the payload PCM data streams.

(5) Checkout of payload subsystems and on-board payload controls by exercising each of these units through potential modes they may face during flight. This requirement is intended to be satisfied primarily by virtue of the fact that all of the Orbiter hardware interfaces are being supplied. Since it is not within the scope of this proposal to provide application software, it can only be stated that the hardware will be supplied which will support the simulation of the flight modes of operation.

(6) Provide an interface for simulating uplink/downlink channels to and from the payload. This capability is provided in the uplink simulator, the PDI/PSP simulator, and the wide band recorder. Only attached payload uplink/downlink capability is proposed (no R. F. Capability).

E. Accepts digital discretes and analog data from the payload-under-test. The IVE Electrical Subsystem Test Measurement Unit performs out-of-tolerance monitoring on all signal characteristics. This is accomplished through the ability to monitor any signal interface between the payload under test and the test system.

F. The system provides a nominal 28 vdc to the payload subsystems. Due to the critical nature of payload power, control and monitoring of the 28 vdc power source is accomplished in the Caution and Warning Subsystem. Fuel Cell simulation is provided.

G. The proposed system provides for the monitor and control of payload coolant. This function will be implemented in the Caution and Warning subsystem.

H. Provide a means of training crew and personnnel for payload operations.

6.3.1 Operator Console

The proposed Integration Verification Equipment operators console consists of twelve categories of hardware components:

1. Controller/Central processor unit (C/CPU)

2. Standard C/CPU support peripherals

   a. 2.5 M byte disc

   b. 75 IPS, 9 track, 800 BPI tape

   c. 150 CPM card reader

   d. 300 LPM line printer

   e. CRT/keyboard

   f. 300 char/sec paper tape reader

3. Time Code/Master clock generators

4. Standard Shuttle Data Bus Interface (2 channel 28 bit Serial Word Simulator/Serial Word Monitor)

5. Standard Shuttle Multiplexer/Demultiplexer Simulator

   a. Discrete input/output unit

   b. Serial input/output unit

   c. Analog input/output unit (actually packaged with the Caution and Warning subsystem)

6. Caution and Warning subsystem

   a. Payload power monitor/control

b. Payload coolant monitor/control

c. Discrete caution and warning monitor

d. Analog caution and warning monitor

e. Standard Shuttle MDM analog I/O

7. Uplink (Command) simulator

a. Ku-Band uplink

b. Payload Signal Processor (PSP) uplink

8. Test Measurement Unit

a. Wide band recorder

Patching network
Bit synchronization and control
Tape Search Unit

b. Oscilloscope

c. Digital Voltmeter

d. Frequency Counter

9. Programmable patch panels

a. GSE through-put switching

b. System reconfiguration

c. Variable signal level module

10. Payload Data Interleaver/Payload Signal Processor Simulator

a. PDI input subsystem

b. PSP input subsystem

11. Audio Distribution Subsystem

a. Amplifier

b. TV monitors

c. Control panels

6.3.1.1 C/CPU Description

The proposed Controller/Central Processor Unit (C/CPU) is a commercial-off-the-shelf mini computer. The unit includes 64 K 16 bit words of 800 nanosecond core. Core memory is interleaved to allow for increased system throughout. The unit also contains a memory allocation and protection unit for efficient use of core memory. Other features include writeable control store for user defined instructions, high speed multiply/divide, floating point hardware, power fail/auto restart, and automatic program load.

The unit is contained in a standard 19 inch rack mounting with space available for 32 logic boards. In the proposed configuration, 27 of the 32 available slots are taken up. This leaves room for five additional modules for expansion if needed.

System options and sizing are based on previous experience at Rockwell International - Space Division and on anticipated requirements for payload checkout. (e.g., 64K memory based on 32K for user application program and 32K for operating system, I/F buffers, interrupt handlers, I/O drivers etc.) Selection of the C/CPU was based upon execution rate and more importantly, available software and programmer experience.

6.3.1.2 Standard C/CPU Support Peripherals

a. 2.5 M byte cartridge disc system - required for operation of RDOS (vendor standard software), also used for storage of user programs and data.

b. 75 IPS, 9 track, 800 BPI mag tape - required for creation of data tapes for verification of run, also used for loading software system and subsystems during system initialization.

c. 150 CPM card reader - normal method of user program parameter initialization, also used during program development.

d. 300 LPM line printer - used for test run summaries and post processing, also used for software development.

e. CRT/keyboard - used for primary system control and operation.

f. 300 char/sec paper tape reader - used primarily for system maintenance.

6.3.1.3 Time Code Generator/Master Timing Unit Simulator

This subsystem consists of a commercial Time Code Generator modified to generate GMT and MET. An interface to the C/CPU processor is provided for presenting and reading GMT and MET. A real time programmable count down clock with a resolution of 1 millisecond or 1 microsecond is provided. Standard Orbiter clocks are provided.

6.3.1.4 Standard Shuttle Data Bus Interface

This subsystem consists of a 28 Bit Serial Word Simulator/Serial Word Monitor (SWS/SWM). This unit is a standard item in use at Space Division and provides simulation of a GPC/IOP or other bus device such as an MDM. It is capable of data bus commmunication with either standard or non standard protocol.

6.3.1.5 Standard Shuttle Multiplexer/DeMultiplexer Simulator

This subsystem is further subdivided into discrete I/O, analog I/O and serial I/O. The analog I/O is packaged with the Caution and Warning subsystem. The discrete I/O and the serial I/O are packaged independently.

The discrete module consists of several sections.

a. Deskew logic to permit the simultaneous sampling of input states or simultaneous setting of output states.

b. Holding registers for all output states.

c. Modularized 28 volt and 5 volt input and output signal conditioners.

Minimum time to set up or sample 16 bits of discretes is 4.4 microseconds. System software may set timing between samples to duplicate FCOS operation. Final counts on the relative quantities of 28 and 5 volt drivers and receivers will be determined when payload test requirements become more definitized.

The serial I/O module consists of 6 identical serial channels built with modular techniques. Each channel will duplicate standard MDM timing. Each will communicate with a separate data buffer in the C/CPU memory using direct memory access techniques. Each channel may be individually controlled by the C/CPU using standard program controlled input/output

instructions. Diagnostic hardware capability will be built in.

The analog I/O capability is described with the Caution and Warning subsystem.

6.3.1.6 Caution and Warning Subsystem

The Caution and Warning (C&W) subsystem provides a simulation of Orbiter/Payload C&W analog I/O, and power/thermal monitor and control. This grouping was based upon similarities between hardware functions and an attempt to reduce overall cost by eliminating redundant hardware. Microprocessor and high speed A/D and D/A technology is used for efficienc and flexibilitv.

The proposed subsystem consists of off the shelf A/D and D/A modules integrated with a microprocessor. The microprocessor controls A/D conversion, multiplexing, and limit checking and provides buffering for variable limits. Parameters may be preset from the C/CPU and any out-of-limit condition will cause an interrupt to the computer.

The state of critical discretes is monitored with change of state detection logic. A change of state of any parameter will cause an interrupt to be given to the C/CPU. It will be possible to select which parameter changes will cause a C&W interrupt. Response time to a discrete change of state will be dependent upon hardware latency (approximately 40 microseconds) plus a variable software latency.

Both payload power and payload thermal control systems may be monitored via the C&W system. For the purpose of fuel cell simulation, an analog output control voltage for the power distribution system is availat Power and thermal control may be accomplished from the C/CPU; however, manual overrides and limits are provided to prevent possible damage to payloads.

Due to the requirement for analog/digital and digital to analog devices in the C&W subsystem, the MDM analog I/O simulation has been packaged with it. There are a total of thirty-two analog input channels provided. Analog output will be provided as needed. C/CPU I/O is a accomplished using DMA for parameter/status reading and PCØ/PCI for control.

6.3.1.7 Uplink (Command) Simulator

Payload commands are generated through a Ku-Band or Payload Signal Processor Uplink. The Ku-Band uplink consists of a NRZ-L (convolutional) 1 MBPS signal with a clock. The Ku-Band simulation unit consists of a

NRZ-L driver, a formatter to perform convolutional encoding and to insert data (commands) into the convolutional bit stream, a format program buffer, a command word buffer, and an interface to the C/CPU computer. The formatter will cause transmission of a continuous stream of command information after being started into operation from the C/CPU. Format program and command information for uplink to a payload is transferred from the C/CPU via DMA. The C/CPU controls uplink operation via PCØ/PCI.

The PSP uplink unit has the same physical structure as the Ku-Band uplink with the exception of having an 8 KBPS Bi-Ø-L output driver. C/CPU I/O techniques are kept the same, despite the lower data rate for the sake of reliability, simplicity of design, and simplicity of software generation and operation.

If a Payload Interrogator interface were required, it would be packaged in this subsystem using similar techniques. Microprocessor techniques will be used where data rates permit.

6.3.1.8 Test Measurement Unit

This unit consists of an oscilloscope, Digital Volt Meter (DVM) frequency counter and wideband recorder. It has been the experience of Space Division personnel that these units are adequate for measurements required during equipment integration processes. It will be possible to measure any interface signal within the system since all signals are present at the patch boards.

a. The Wideband Recorder provides the basic recording capability. It has been designed to permit expansion to allow for recording and playback of all payload data streams, including the 4.0 MHz Analog and the 50 MHz high speed digital data.

The basic system includes a 28 channel wideband recorder with electronics supplied for 14 of the 28 record and reproduce heads. Amplifiers and interface units are proposed which will allow direct recording on all 14 tracks in either digital or analog mode. FM circuitry is proposed for one channel only (according to presently known requirements). Provision is made for recording time using either IRIG B or IRIG G formats. A Time Code Reader, programmable from the C/CPU is provided.

Reproduce amplifiers are provided. However, it should be noted that without special deskew logic, synchronization between tracks during play back degrades at a rate directly proportional to the relative speed between record and playback modes. For example data recorded at 120 IPS

and played back at 15 IPS would have 8 times the skew during play back. This has several implications.

1. Data playback occurs at the same speed as record.

2. The data from each channel is analyzed independent of the timing to the other channels. Or

3. Synchronization is not required to an accuracy of greater than 128 microseconds for data recorded at 1/32 speed.

Based upon the above, it is apparent that synchronization and therefore post processing analysis will be some what degraded for the higher data rates, using the basic system. It is recommended that the expansion to handle the higher data rates be delayed till just prior to actual need dates.

b. The oscilloscope, DVM and frequency counter have been provided for the evaluation of signal characteristics (e.g., signal amplitude frequency, period, repitition rate). These units provide the flexibility required to measure a changing series of signal types from different payloads with a minimum of hardware/software reconfiguration or procedural change.

6.3.1.9 Programmable Patch Panels

These units provide the flexibility necessary for the anticipated needs of a payload interface verification operation. The programmable patch panels allow for ease of system reconfiguration and for access to all interface signals. A separate patch board is set up for each test configuration and for IVE diagnostic purposes.

The programmable patch board also permits a simple technique for GSE through-put switching. Each patch panel is broken into three sections.

1. This section is wired to the Payload cable connectors.

2. This section is wired to the GSE cable connectors.

3. This section is wired to the IVE electronics.

Thus it is possible to patch from Section 1 to 3 for IVE/Payload tests, from 2 to 3 for GSE/Payload tests, or from 3 to 3 (wrap around) for diagnostic tests.

This subsystem also includes a patchable variable signal level unit which allows varying the signal amplitude through normal flight operational ranges. A set of manual controls for changing the signal characteristics is provided.

6.3.1.10 Payload Data Interleaver/Payload Signal Processor Subsystem

This unit provides for simulation of PDI/PSP (downlink) interfaces. The unit includes 6 bit synchronizers, 2 frame synchronizers, and one word selection unit. Microprocessor technology is used for the frame synchronizers and the word selection unit. Parameter storage is provided external to the microprocessor and the C/CPU. Parameter storage is set up via DMA from the C/CPU. Control/status information for both frame synchronizers and the word selection unit is transferred from/to the C/CPU via PCØ/PCI.

The bit synchronizers are bit rate tunable and have fixed data formats. These units are plug in type so that is is simple to change the data format by plugging in a different module. Input to the bit synchronizers comes from the programmable patch panel. It is therefore possible to bring in data either direct from the payload or through playback of recorded data.

It will be possible to simultaneously take selected data from all six streams (5 PDI and 1 PSP). It will be possible to control the number of words from each stream, which words are needed, and where they are to be stored in the C/CPU memory. Data storage pointer lists are to be kept in C/CPU memory for ease of program control.

6.3.1.11 Audio Distribution Subsystem

Dedicated interface for providing/accepting Orbiter or payload audio communication signals. Provides amplification, control and distribution of audio signals and consists of an amplifier, distribution network and tone generator. Provides audio interface between the aft flight deck and operators console.

6.3.1.12 Video Distribution Subsystem

Dedicated interface for providing/accepting Orbiter or payload video data. Provides for control and distribution of video signals and consists of cameras, TV monitors and control panel.

6.3.2 Aft Flight Deck Set

Figure 6-3 is representative of the layout of the Aft Flight Deck (AFD) which provides operational simulation of the AFD Orbiter to payload interfaces. The X_o576 bulkhead payload electrical service panels and interconnecting flight configuration cabling.

The AFD consists of the following electronic assemblies which are provided for the installation of payload related control and display equipment and have a direct impact on payload operations: Mission Station (MS), On-Orbit Station (OOS), Payload Station (PS), an air blowing cooling system and control and display panels for the following functions:

- Audio
- Closed Circuit Television
- Lighting
- CRT/Keyboard
- Power
- Caution & Warning
- Safing
- Mission Timing

Presently no mode controls are provided for the control of simulated Orbiter C&DH subsystems (Ku-Band, S-Band and payload signal processors) from the AFD. However, the AFD is provided with close-out panels simulating the location and size of the C&DH subsystem display and control panels and may be modified at a later date.

6.3.3 DC Power Unit

DC power to the payload buses is provided by the DC power unit shown in Figure 6-17. The DC power unit consists of a commercial DC power supply, power switching assembly and distribution module. Transient characteristics of the Orbiter fuel cell in the 0 to 1Hz region are simulated by (1) sensing the load changes, feeding, these changes to the C/CPU where algorithems approximate the load line curves of the fuel cell, (3) the resistance output of the C/CPU which is directly related to the payload subsystems load changes is fed to the DC power supply

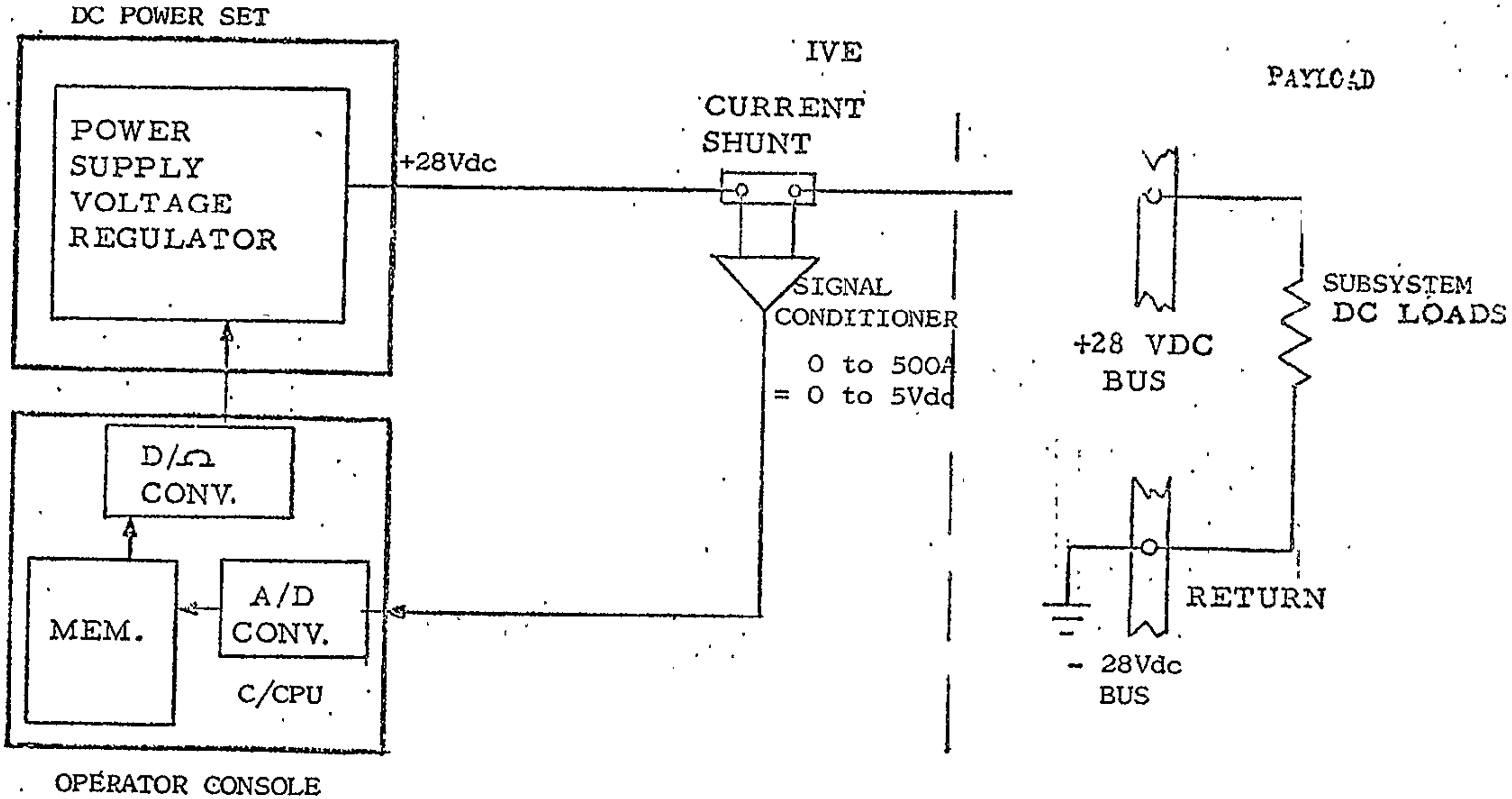


FIGURE 6-17 FUEL CELL SIMULATION - 0 to 1 HZ

voltage regulator. An increasing load change will decrease the output of the DC power supply.

6.3.4 Data Management (Software System)

The IVE electrical subsystem will provide a data management control system consisting of the Software shown in Figure 6-18 and the peripheral elements shown in Figure 6-19.

The major programs of the IVE software system are (1) the system support software package providing control of all peripherals, special purpose interface handlers (formatters, decoders), (2) a test application software package which provides a library of subroutines for performing payload subsystem performance checks and interface verification (payload test program) and (3) a software package containing programming aids (assembler routines, linkage editors and couplers for operating languages). The primary functions of the IVE operating system will be verification of hardware interfaces between the Orbiter and the payload. The operating system will not have the capability to verify the payload user software, however, the capability to develop and test software programs and check sizing and timing is provided.

The payload user may write test application programs in either Fortran V, C/CPU assembly language, HAL/S or GOAL. The HAL/S and GOAL compilers are optional and may be obtained with the capability of compiling programs off-line on an IBM 360 or on-line on the IVE C/CPU.

The IVE software operating system provides the user with the capability to: (1) select/vary the real time display format, (2) control test operations from the video terminal keyboard, (3) select magnetic tape recording modes for recording test data, (4) provide automatic/manual start/stop test application program execution, (5) perform an orderly equipment shutdown by test application program or keyboard action, (6) provide modular input/output programs which may be selected by test application programmers by system calls. The peripheral C/CPU interface is shown in Figure 6-19.

The electrical subsystem programs will execute in two major modes of operation. The first is the test application program initialization mode. This function is used to: (1) define the test application program input/output variables and their characteristics to the system, (2) define test application program display formats to the system, and (3) assign values to program variables and constants for test application program initialization. The second major mode of operation for the electrical subsystem is the on-line mode. This function will be used to: (1) perform actual on line test conduct (2) request display pages on the CRT, (3)

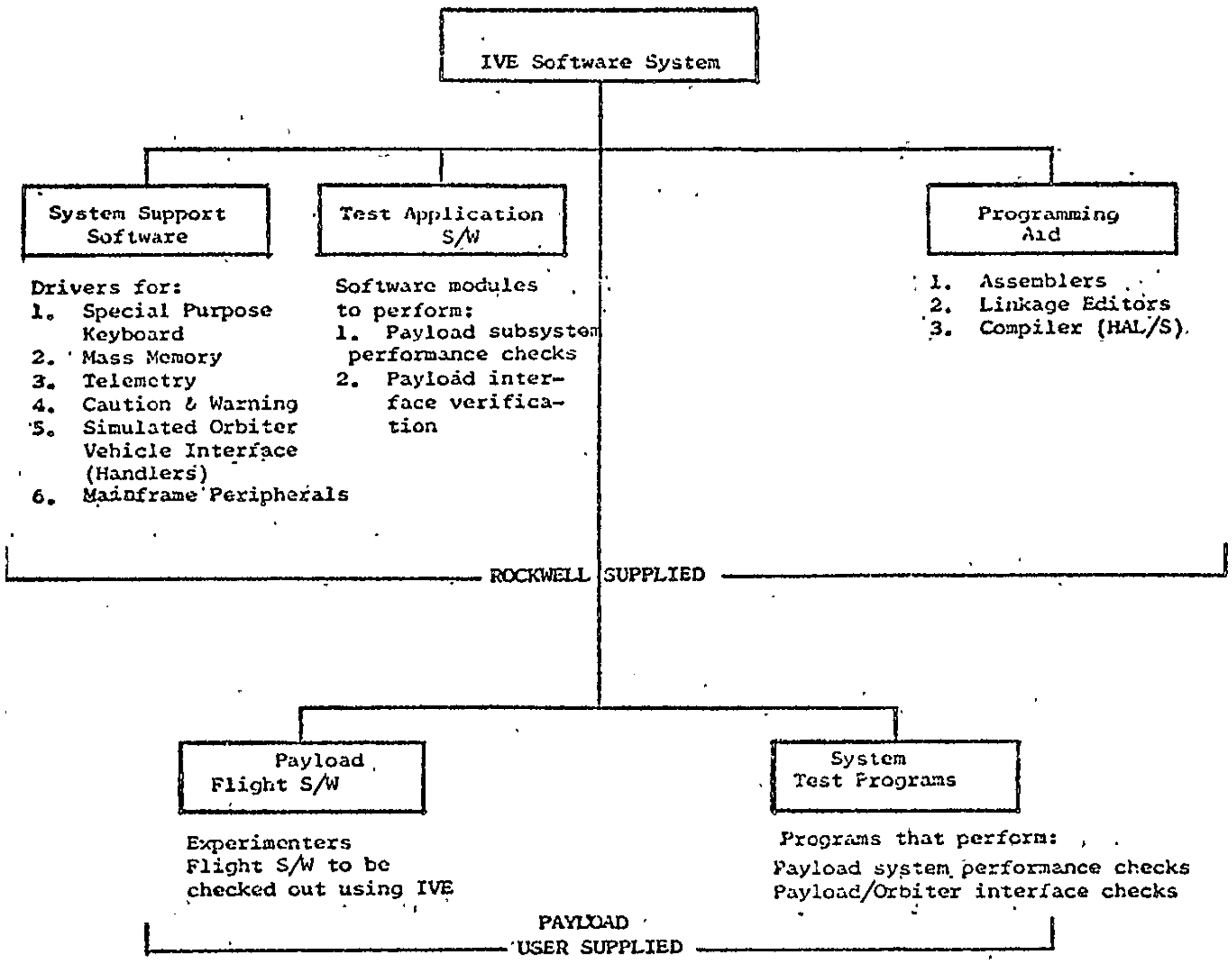
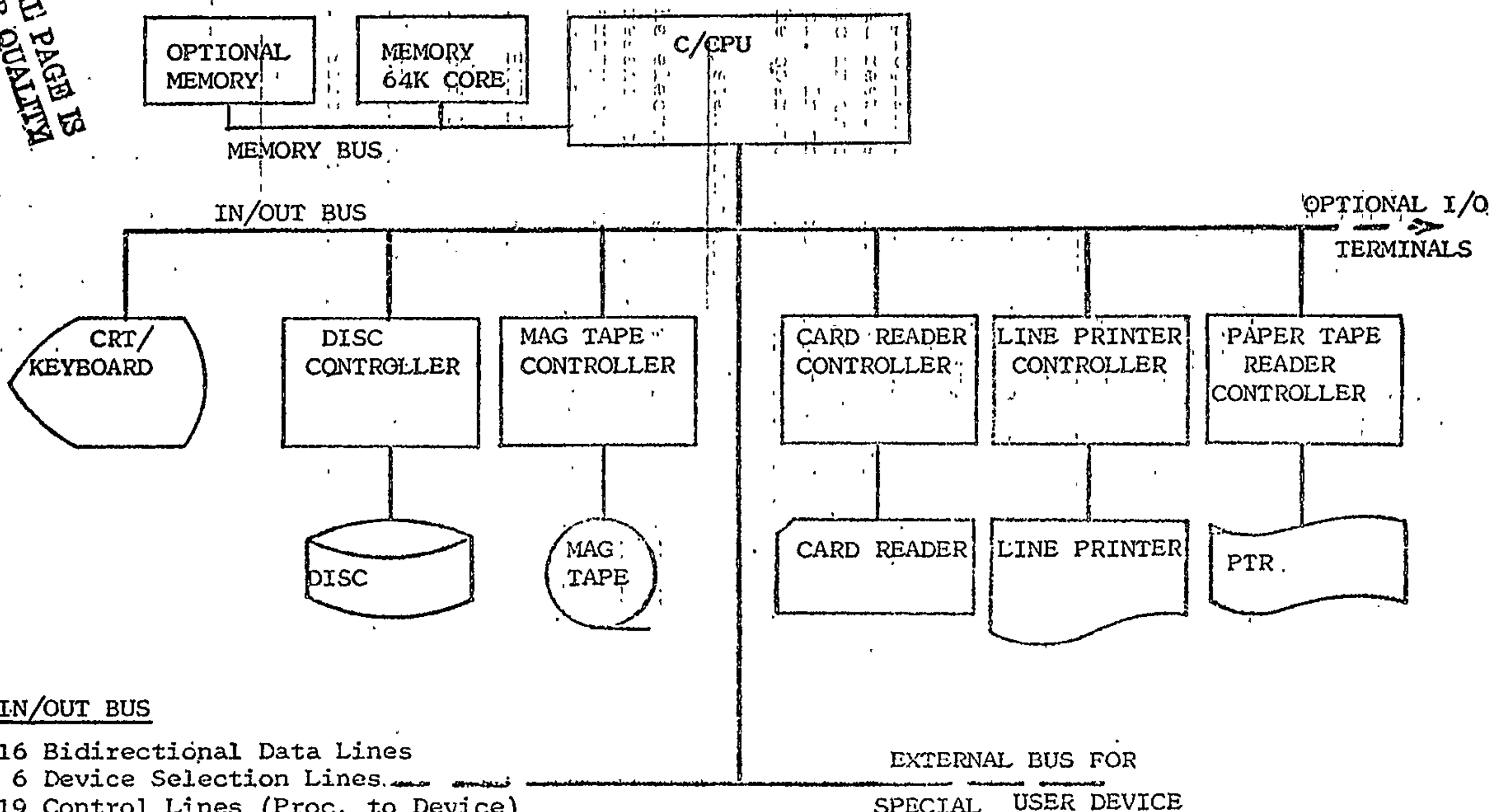


Figure 6-18 SOFTWARE SYSTEM



IN/OUT BUS

16 Bidirectional Data Lines
6 Device Selection Lines
19 Control Lines (Proc. to Device)
6 Control Lines (Device to Proc.)

Figure 6-19 DATA MANAGEMENT SYSTEM - C/CPU & PERIPHERALS

select/deselect magnetic tape recording modes, (4) start/stop test application program execution, (5) selectively read and write program and I/O data, (6) print test results and intermediate test results in the line printer, and (7) request an orderly shutdown of payload equipment.

The electrical subsystem will operate in two test modes: (1) a listen mode to monitor,record or analyze the payload response data or process the data to derive its information content. The listen mode will be capable of monitoring/checking impedances, signal/power characteristics, timing and data content. (2) A command mode to command and send data to the payload. The commands/data will be generated over the flight range of values and will stimulate the payload with signals that conform to Orbiter specifications. The capability to command the payload and monitor responses simultaneously is provided.

The IVE electrical subsystem may be operated in the automatic or the manual mode. In the automatic mode all test functions are completely under program control (i.e. displays automatically updated, processing of payload responses and commands to the payload are initiated by pre-programmed instructions) and operator interaction is only through program control. In the manual mode the C/CPU is placed in a monitor/check mode and the operator has full control of all displays and test functions.

6.3.5 System Limitations

The electrical subsystem will not perform the following functions at the present stage of development; however, due to the flexibility and modularity of the hardware and software design these features are not precluded from being incorporated at a later date:

a. EMI/EMC testing

b. Off limit testing

c. RF checkout (payload interrogator/detached payload interface)

d. Software validation

6.3.6 Optional Equipment

6.3.6.1 Preflight Umbilical Electrical Panel

A prefabricated panel will be provided at the T-4 prelaunch umbilical to simulate specific payload to Orbiter electrical interfaces.

The assembly will consist of a panel and connectors (size and quantity TBD).

6.3.6.2 X_o1307 Electrical Service Panel

An electrical service panel will be provided at the X_o1307 bulkhead to simulate the specific payload to Orbiter interfaces. The service panels will provide an interface for secondary power, communications and data ground monitoring signals. The assembly will consist of a left and right hand panel assembly.

6.3.6.3 Payload Bay Floodlight Assembly

Floodlights will be provided at the X_o576 and X_o1307 bulkhead and X_o750, 979.5 and 1140.67 stations for payload operations. The units will be remotely controlled from the aft flight deck stations and provide a lighting angle of approximately 135°. The assembly will consist of floodlights, support brackets, electrical cables and control switches.

6.3.6.4 CCTV Assembly

CCTV cameras will be provided at the X_o576 and X_o1307 bulkhead.

The units will be remotely controlled from the aft flight deck stations and provide remote monitoring of payload related activities from the crew compartment. The assemblies will consist of cameras, pan and tilt units, supports, electrical cables, control panels and monitors.

A interface will be provided for the use of a third TV camera which may be required by the payload user to simulate operation of TV camera which is located on the RMS.

6.4 FLUID SUBSYSTEM

The IVE simulates all Orbiter payload fluid accommodations. The limited number of payloads requiring fluid interfaces resulted in categorizing the fluid subsystem as optional equipment. Hole cutouts and other necessary mounting provisions are provided in the Standard Horizontal IVE to accept the following fluid subsystem elements:

a. Environmental Control Unit Set

b. X_o1307 Payload Fuel and Oxidizer Panel Assemblies

c. T-O Umbilical Fluid Interface Assembly

d. Preflight Umbilical Fluid Panel Assembly

e. Leak Detection Assembly

f. Ground and RTG Cooling Assembly

6.4.1 Environmental Control Unit Set (ECUS)

Active cooling of the payloads in the Orbiter mid-body is provided by the ECUS. The ECUS consist of a commercial heat exchanger (chiller), controlled display panel, payload interface panel assembly, fluid lines and fittings, and a purge and test unit as shown in Figure 6-20.

The coolant unit is used to transfer heat from the payload subsystems to the IVE active thermal control subsystem and is compatible with water or Freon 21.

Fluids from the payload will be accepted by the coolant unit at a maximum temperature of +135°F. The fluid will be cooled by the chiller to a temperature of +45°F and returned to the payload subsystems. The heat rejection capacity of the coolant unit exceeds 29,500 Btu/Hr, will operate up to a working capability of 200 Lbs/in^2 and deliver coolant flows to the payload that conform to the Orbiter specifications.

A purge and test unit will be provided for purging the fluid lines between payloads and performing leak checks.

The coolant unit will interface with the payload at the X_o636 interface. The IVE will provide a fluid interface at the X_o1307 bulkhead consisting of flight type fluid connectors for leak checking only.

For more detailed information on the requirements for the ECUS see Section 10.6.1 of Vol. III, Horizontal IVE Specification Data.

6.4.2 X_o1307, T-0 Umbilical, Preflight Umbilical, Ground and RTG Cooling

Refer to sections 10.6.2 through 10.6.6 of Vol. III, Horizontal IVE Specification Data for a description of the performance and design requirements for the IVE.

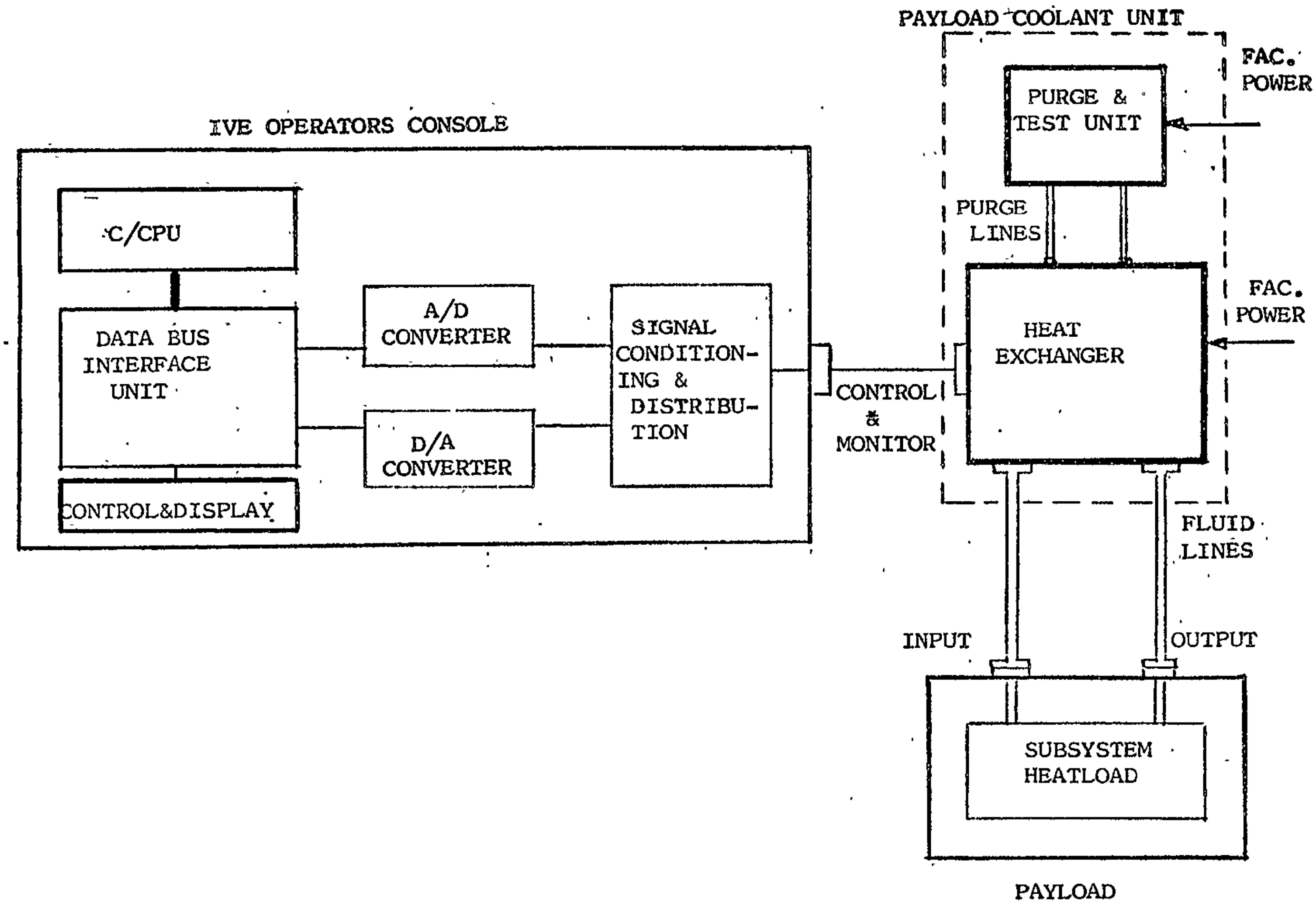


FIGURE 6-20 ENVIRONMENTAL CONTROL UNIT SET

7.0 HORIZONTAL IVE CONCEPT DEVELOPMENT TRADES

7.1 TRADE STUDY CRITERIA

Design concept trade studies were performed to determine the preferred design approach for the IVE primary structure, payload retention, and the electrical subsystem. The trade studies were governed by the evaluation criteria listed in Table 7.1.

TABLE 7.1 IVE DESIGN EVALUATION CRITERIA

- o Performance
- o Simplicity
- o Modularity
- o Hardware Availability
- o Commonality
- o Operational Flexibility
- o Common Structure Design for Horizontal and Vertical IVE Operation
- o Ease of Addition/Removal of Payload I/F Optional Equipment
- o Manufacturing Complexity/ Tooling
- o Transportability
- o Ease of In-Field Assembly
- o Configuration Control
- o Comparative Cost
- o Facility Support

7.2 HORIZONTAL IVE STRUCTURE AND MECHANISMS CONCEPT TRADES

7.2.1 Primary Structure

The initial IVE structural concept was greatly influenced by Spacelab requirements including horizontal operation only, air transport to meet a tight delivery schedule for delivery to ERNO, multiple assembly/ disassemble for use at various geographic locations and storage. These considerations resulted in a modular mid-body consisting of four sections as shown in Figure 7-1. Each mid-body section was comprised of five subassemblies, two right and two left hand vertical subassemblies and a horizontal subassembly sized to comply with transportability requirements of MIL-Standard 1366.

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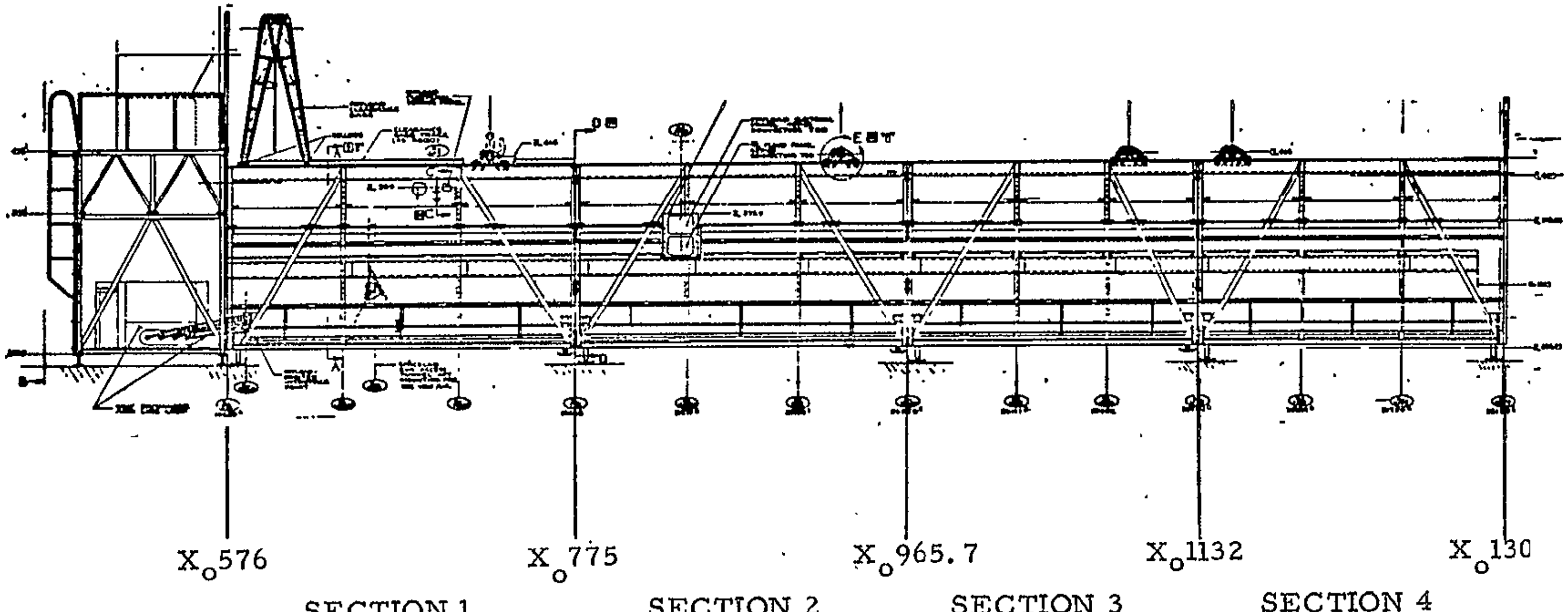


FIGURE 7-1 HORIZONTAL IVE INITIAL STRUCTURAL DESIGN

Prior to the start of the horizontal IVE preliminary design effort, the requirement for air transportability was relaxed allowing section assemblies with lengths in excess of 20 feet resulting in the development of a 3 section mid-body as shown in Figure 6-1.

7.2.1.1. Concept Evaluation

Two basic design concepts were evaluated. Concept A as shown in Figure 7-2. Concept B was developed during the latter part of this study and deviates from Concept A with respect to the approach used to interconnect the two side truss assemblies. Concept A employs a welded center (panel) assembly. Concept B employs three independent cross beams.

Concept B was selected for further preliminary design analysis based on consideration of (1) structural loading and member sizing, (2) ease of manufacturing and assembly, (3) minimal tooling requirement and (4) design simplicity for compensating for design and manufacturing tolerances during each section assembly and section-to-section assembly (require no shimming on assembly). Three side truss configurations (Figure 7-2) were evaluated to determine the preferred (most efficient) common structural design compatible for IVE operation in either a horizontal or vertical position. A comparative load analysis of the three truss configurations (simplified pin ended design) was performed to determine the most efficient structural design approach with respect to total weight. The modified Warren Truss resulted in the lowest truss assembly weight. Also the Warren truss (and 3 panel Pratt) requires fewer members (9) than the four panel Pratt which requires 11. The subdivided Warren truss was selected for the IVE preliminary design on the basis that it provides the best support for the combined bending and torsional load in the longeron (horizontal configuration) with the minimum required amount of material and miminum number of structural members.

7.2.1.2 Structure Sizing

A NASTRAN model of the IVE structure was developed to support the design analysis to define structural design requirements, e.g. sizing of structural members and their interconnections. The NASTRAN rigid format #1 was used to determine static load deflections for both vertical and horizontal IVE configurations. The NASTRAN rigid format #5 was used for the IVE structural stability analysis. See NASTRAN manuals for a detailed description of the NASTRAN formats.

A preliminary sizing analysis of the Horizontal IVE Structure considered a 65K pound payload located at any available X_O retention location (length of payload bay), a 6 inch eccentricity at the lower chord support points to the floor, and no side loads. Results indicated that

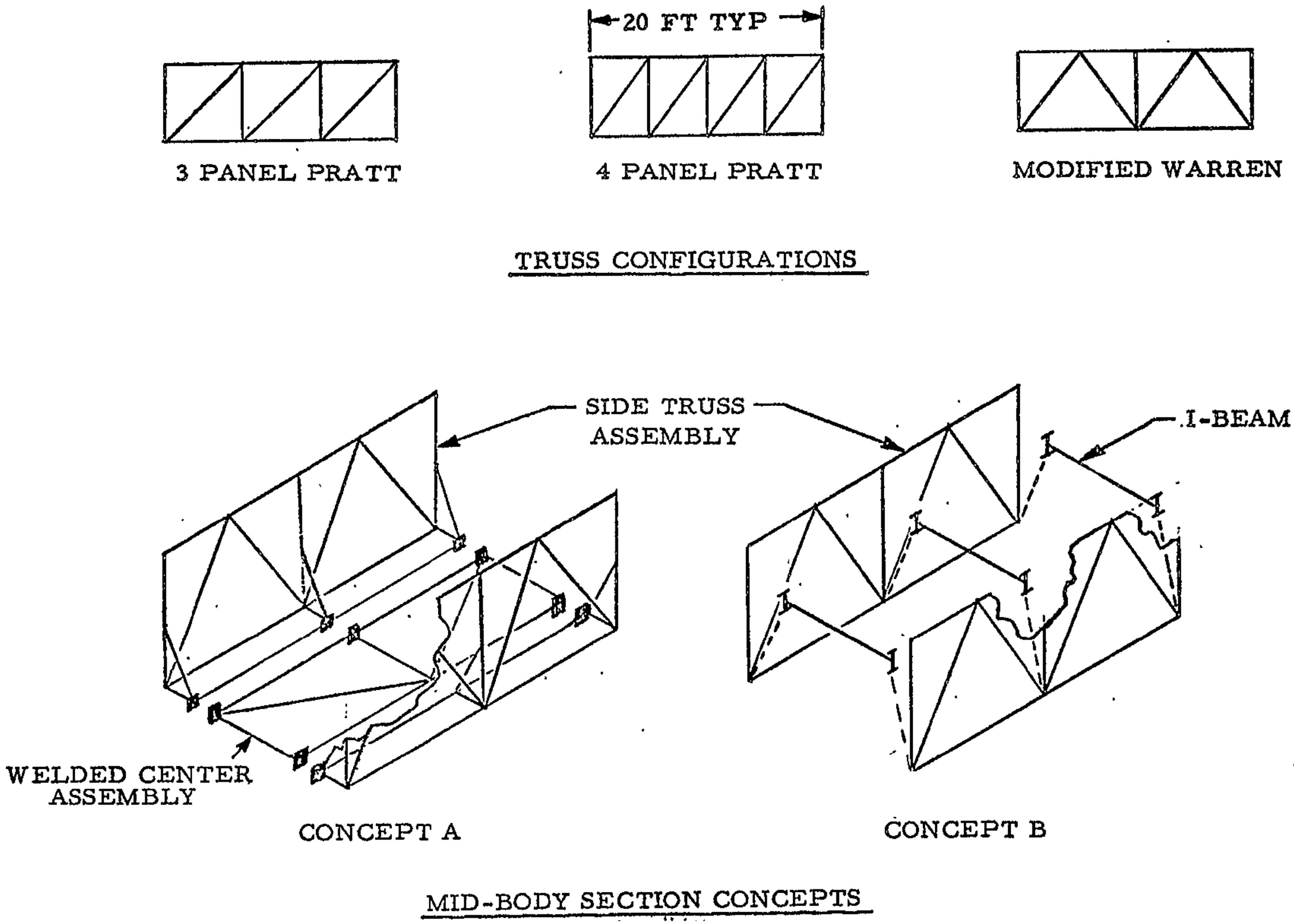


FIGURE 7-2 IVE STRUCTURAL DESIGN TRADES

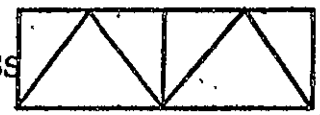
a longeron box section 4" wide by 10" deep with all other structural members 4" by 4" inch box satisfied the Horizontal IVE requirements. This design configuration was used as a satarting point to size the structural members for IVE operation in a vertical as well as horizontal position. Several NASTRAN runs were made varying member sizes and trading off member size of the longeron with stiffeners (bulb angle and clevis mount welded to longeron) to determine the preferred final structure sizing. Figure 7-3 identifies the configurations analyzed and their loading conditions (for critical load point determination in the vertical position). The 6 inch wide members with longeron, lower chord and I-beam cross beams of 10 inches in depth and with longeron stiffening satisfy both horizontal and vertical IVE requirements.

A series of runs (7-22 Figure 7-3) applying a 65K pound vertical load and a 3250 pound side load at the load points 100 to 1120 (identified in Figure 7-4) defined the critical load points and magnitude of the lateral deflection (Y-Y) of the longeron attach points in the horizontal position. An open ended model was analyzed to provide deflection data to determine the potential application of using a section of the IVE as an open ended payload handling/support fixture. The deflection magnitudes shown in Figure 7-4 are much larger than would be incurred by the IVE with X_o576 and X_o1307 structural end ties (bulkhead assemblies). With end enclosures, the maximum deflection of the IVE would be somewhat less than the 0.26 inches indicated at load point 1115. Deflection at load point 100 would be essentially zero and would increase to a maximum at load point X_o1115. It is noted that these deflections are based on a maximum sideload of 10% of the payload. This condition cannot occur at the same time the 32.5K load occurs on the longeron in the vertical direction. Hence, the deflection of the IVE structure in the absence of side loads is essentially zero.

The results of the buckling analysis for the vertical IVE (configuration 3 in Figure 7-3) showing the relationship between the column length and loads are as follows:

Load	Support (X_o)	Factor Safety
65K	1187	20.0
40K	1069	21.4
32K	892	19.1
20K	774	24.8
10K	619	36.1

MODIFIED WARREN TRUSS SELECTED DESIGN APPROACH



NASTRAN MODEL STRUCTURAL CONFIGURATIONS

CONFIG. \ MEMBER		STIFFENER W	STIFFENER W/O	A	B	C	D	E	F
				INCHES					
1	V		X	4	10	4	4	4	4
2	V	X		4	10	4	4	4	4
3	V	X		4	10	4	4	10	4
4	V		X	6	10	6	6	10	6
5*	V		X	4	10	4	4	10	4
6	V			6	10	6	10	10	4
7-22	H			6	10	6	10	10	4

* ASSUMES NO MOMENT TRANSFER AT SECTION JOINT

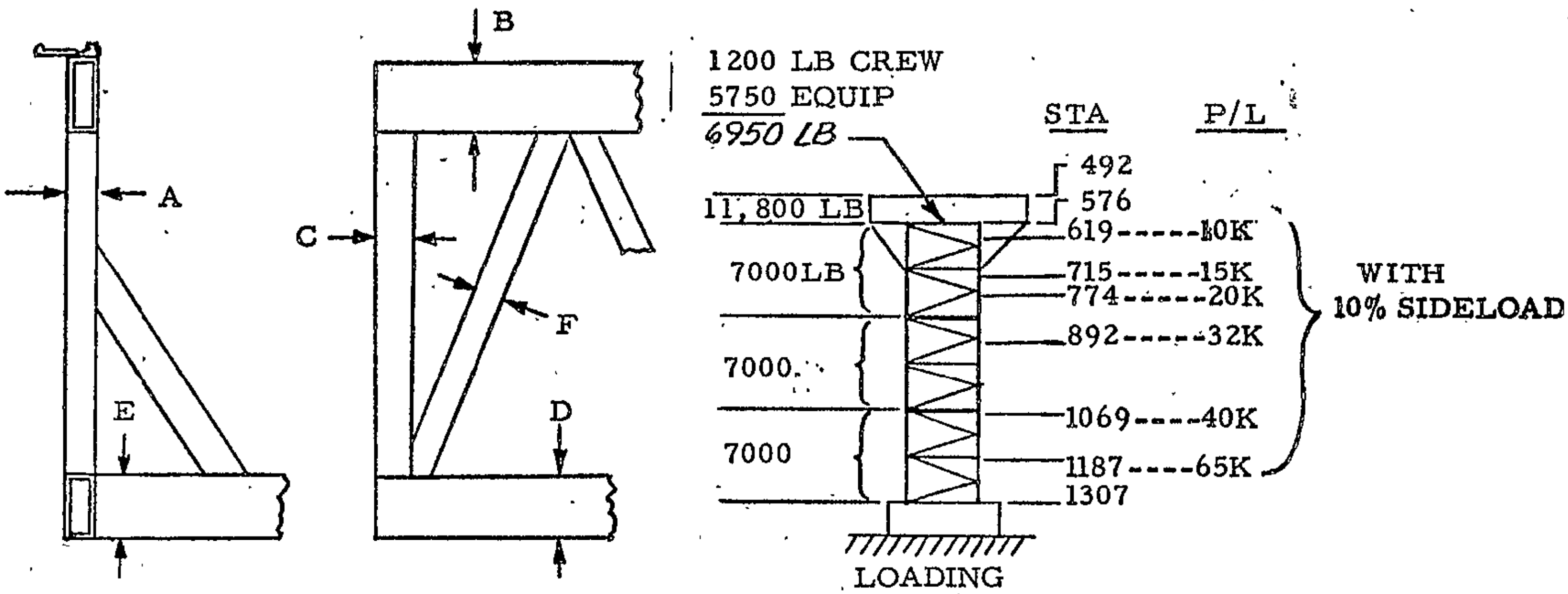
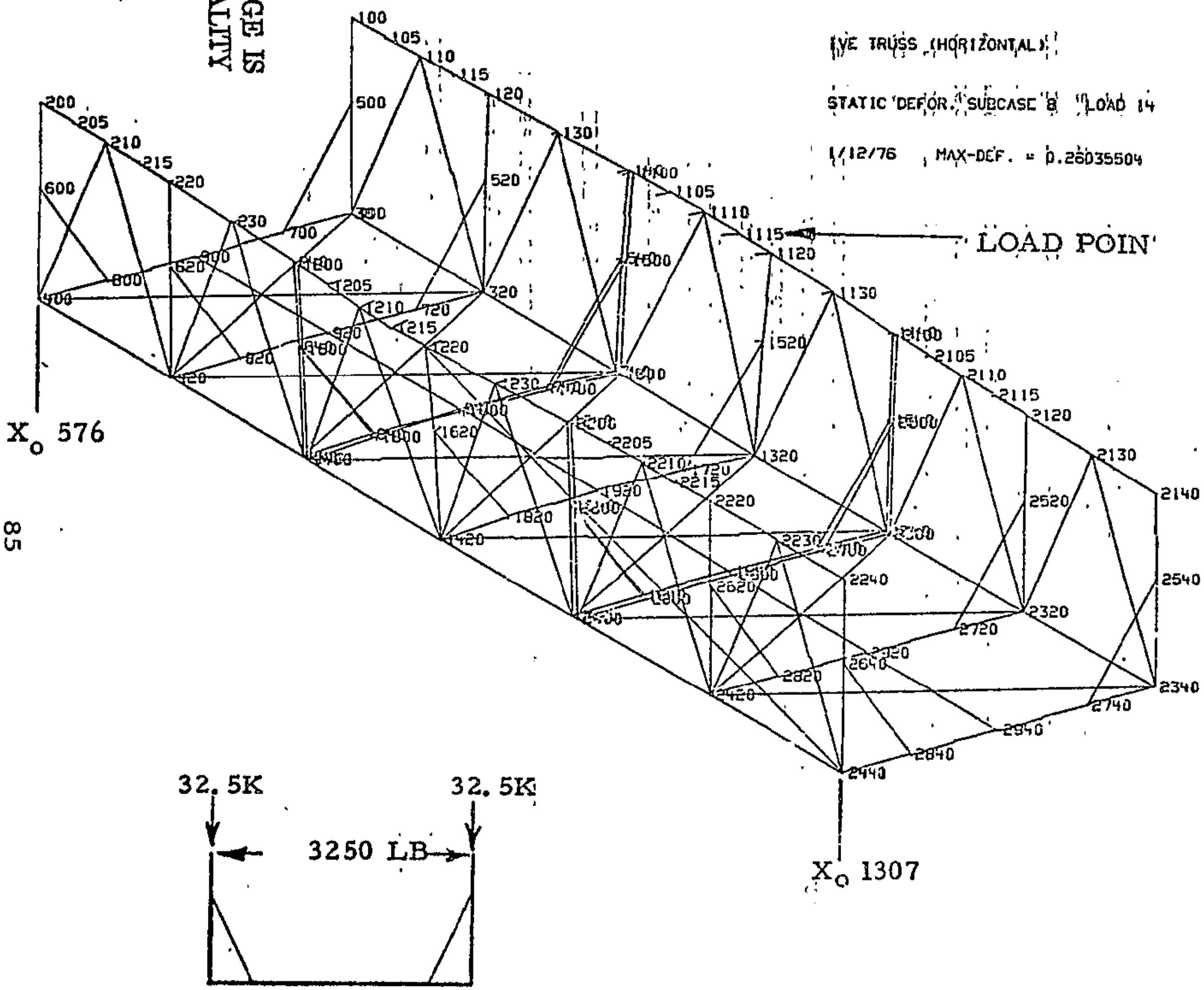


FIGURE 7-3 IVE STRUCTURAL CONFIGURATION



LOAD POINT	MAX DEFL POINT	MAX DEFL (IN)
100	100	.438
105	100	.571
110	100	.325
115	110	.361
120	120	.195
125	120	.291
130	130	.186
135	1100	.283
140	1100	.219
1100	140	.219
1105	140	.284
1110	1110	.178
1115	1115	.260
1120	1120	.161

FIGURE 7-4 HORIZONTAL IVE STRUCTURE DEFLECTION

As can be seen, the worst case does not occur at the heaviest load, but with the 32K load. Figure 7-5 shows the results of the buckling analysis for the final structure (Configuration 6 in Figure 7-3) with the critical 32K load located at X_o892 in accordance with the loading constraints also shown in Figure 7-3. The addition of the X_o576 work platform to Configuration 6 significantly improved the vertical IVE buckling stability resulting in a column buckling factor of safety of 39.01. A detailed load path analysis was conducted (runs 7-22 in Figure 7-2) to size the side truss and cross beam interconnecting plates/bolts and the interconnections between the sections.

7.2.2 Payload Retention

The IVE baseline design concept for payload attachment at the start of this study envisioned a short bridge, with three positions available for the payload attach fitting (Figure 7-6). This design required removing and installing the bolted on IVE bridge from one payload to the next. After setting up for eleven payloads, operational set up costs associated with the payload attach fitting exceed the initial delta cost to provide a continuous simulated bridge the entire length of the mid-body.

Various concepts were considered for the continuous bridge payload retention as shown in Figure 7-7. A qualitative analysis was conducted using evaluation criteria which indicate the degree of design complexity and associated costs. Table 7.2 shows the criteria used and the comparative analysis of the continuous bridge concepts shown in Figure 7-7. The bolted clevis concept was selected as the preferred design concept for the IVE preliminary design.

7.3 ELECTRICAL SUBSYSTEM DESIGN TRADES

Two design concept options were investigated in the development of the IVE electrical subsystem:

OPTION I - Emphasis on use of Shuttle Orbiter design non-flight qualifiable hardware augmented with commercial test equipment.

OPTION II - Use of commercial test equipment using a minimum of Shuttle Orbiter design hardware augmented with hardware designed and developed by Space Division in support of the Orbiter development.

The design deltas in the two options involve only the operators control set. The aft flight deck set and DC power set design are identical for both options. The fuel cell simulator and aft flight deck concepts were

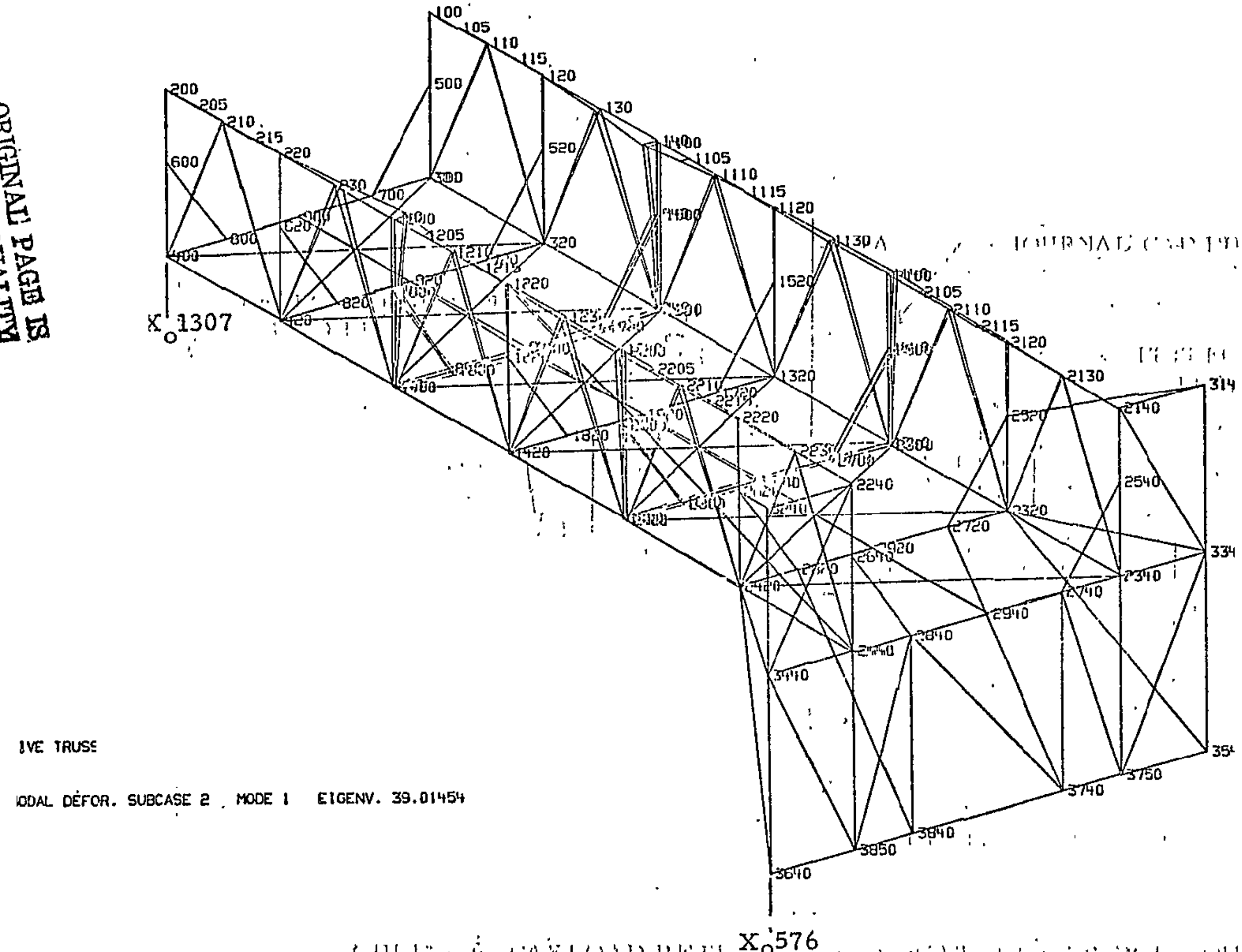


FIGURE 7-5 VERTICAL IVE CONFIGURATION - BUCKLING

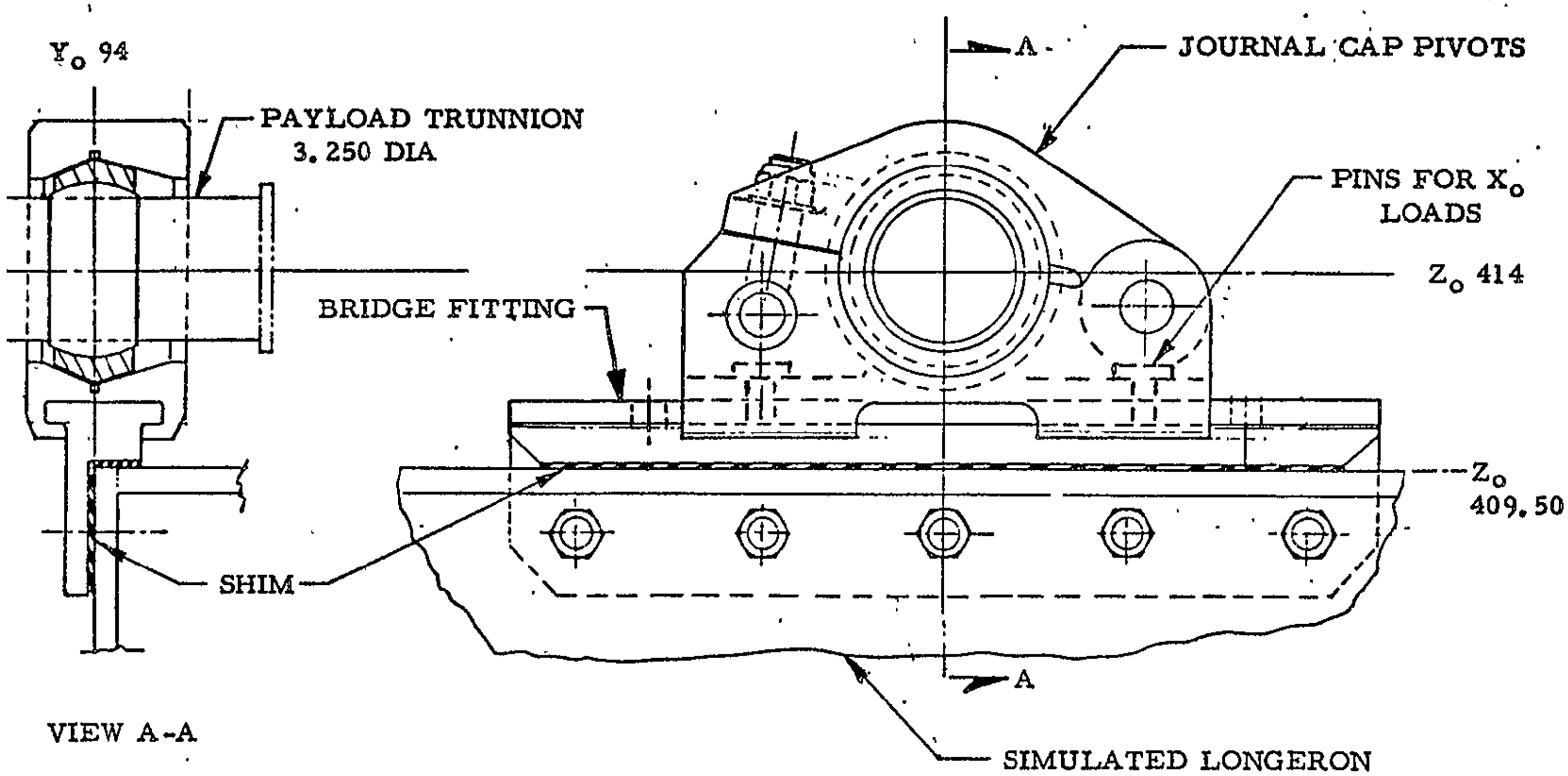


FIGURE 7-6 PAYLOAD RETENTION RELOCATABLE BRIDGE CONCEPT

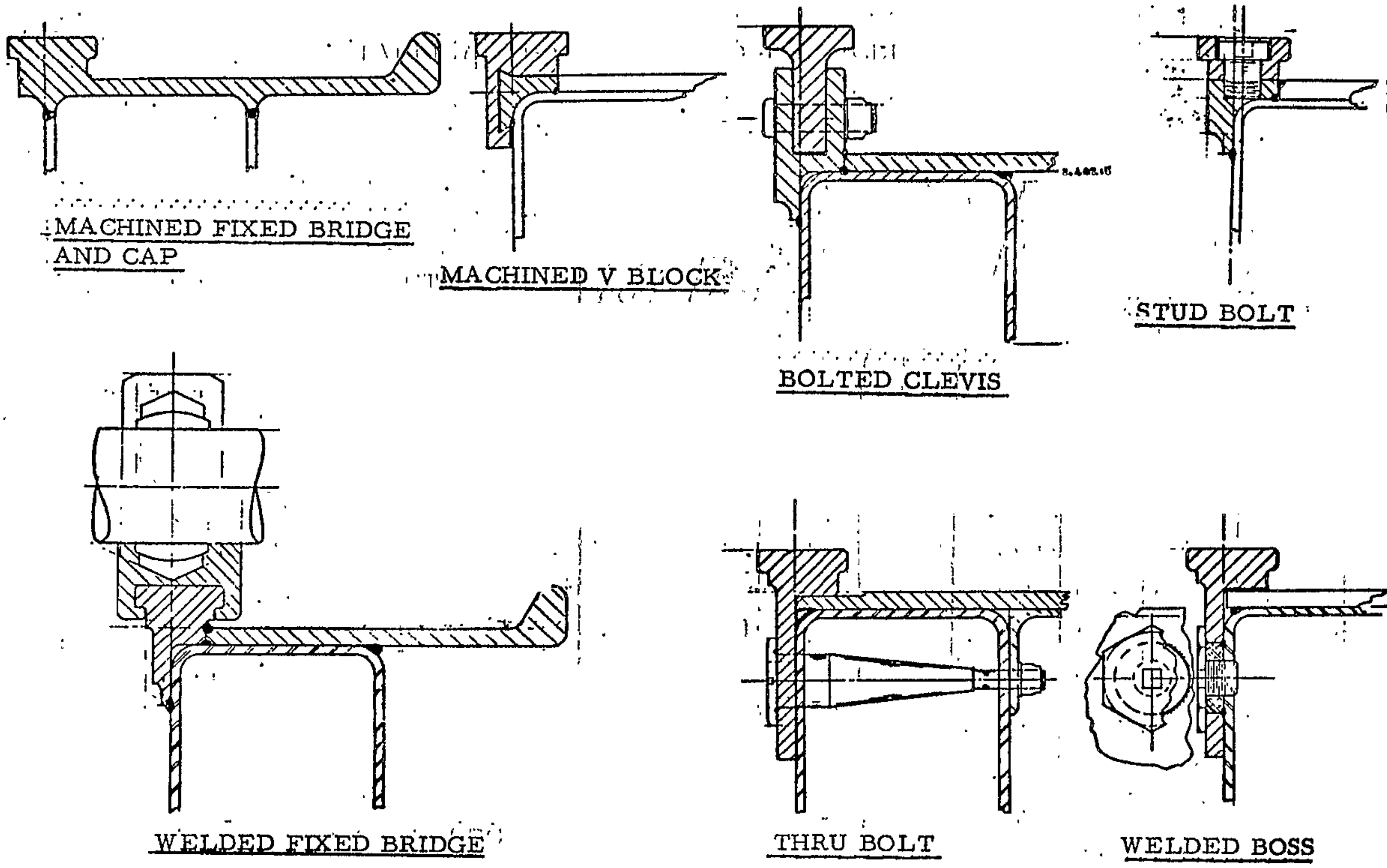


FIGURE 7-7 PAYLOAD LONGERON BRIDGE CONCEPTS

TABLE 7.2 LONGERON BRIDGE CONCEPTS COMPARISON

BRIDGE DESIGN CONCEPT	REMOVABLE BRIDGE	LONGERON WALL BEARING	BOLTING REQMT'S	MACHINING COMPLEXITY	MACHINED SURFACE AREA	WELDING COMPLEXITY	WELDING (INCHES OF)	MAINTAINABILITY
SPACELAB BASELINE	YES	$\boxed{\text{YES}}$	$\boxed{\text{HIGH}}$	LOW	HIGH	N/A	N/A	MED
MACHINED FIXED BRIDGE & CAP	$\boxed{\text{NO}}$	N/A	N/A	HIGH	LARGE	HIGH	LOW	$\boxed{\text{POOR}}$
WELDED FIXED BRIDGE	$\boxed{\text{NO}}$	N/A	N/A	LOW	MED	LOW	HIGH	$\boxed{\text{POOR}}$
MACHINED V BLOCK	YES	N/A	N/A	$\boxed{\text{HIGH}}$	LARGE	LOW	MED	$\boxed{\text{POOR}}$
BOLTED CLEVIS *	YES	N/A	MED	LOW	LARGE	LOW	HIGH	GOOD
THRU BOLT	YES	$\boxed{\text{YES}}$	$\boxed{\text{HIGH}}$	LOW	MED	N/A	LOW	MED
STUD BOLT	YES	N/A	MED	$\boxed{\text{HIGH}}$	$\boxed{\text{LARGE}}$	LOW	MED	$\boxed{\text{POOR}}$
WELDED BOSS	YES	N/A	$\boxed{\text{HIGH}}$	$\boxed{\text{HIGH}}$	LARGE	MED	MED	$\boxed{\text{POOR}}$

$\boxed{}$ IDENTIFIES BASIS FOR CONCEPT REJECTION

* HORIZONTAL IVE SELECTED CONCEPT

dictated by the existing design of the fuel cell simulator at SAIL (NASA/JSC) and the design of the Orbiter aft flight deck electrical subsystem. As a result no trades for the DC power set and aft flight deck set were conducted.

7.3.1 Electrical Subsystem - Option I

Option I design approach relied on the design of the Orbiter hardware components/equipment which interfaces with or supports the payload. Orbiter flight configuration hardware (non-flight qualifiable hardware) with a minimum of commercial test hardware were integrated into the subsystem concept. Orbiter interface elements include communications and data handling (payload signal processor, payload data interleaver, MUX/DEMUX, Ku-Band signal processor, general purpose computer), caution and warning, audio system, video system, recorders, etc., as shown in Figure 7-8. The advantages and disadvantages of Option I are:

ADVANTAGES

- Built-In Performance Monitoring
- Built-In Computer Supervised Monitoring and Control
- Growth Potential for Complete Shuttle Simulation
- Ruggidized Circuitry
- Supports Payload Software Verification
- Bulk of Equipment Under Shuttle Configuration Control

DISADVANTAGES

- Varying of Signals Over Entire Flight Range Not Universally Possible
- Changes In Orbiter Hardware Design Require Design Mods to IVE Hardware
- Hardware Availability Dependent on Shuttle Program Requirements
- Individual Equipment Troubleshooting or Verification Difficult

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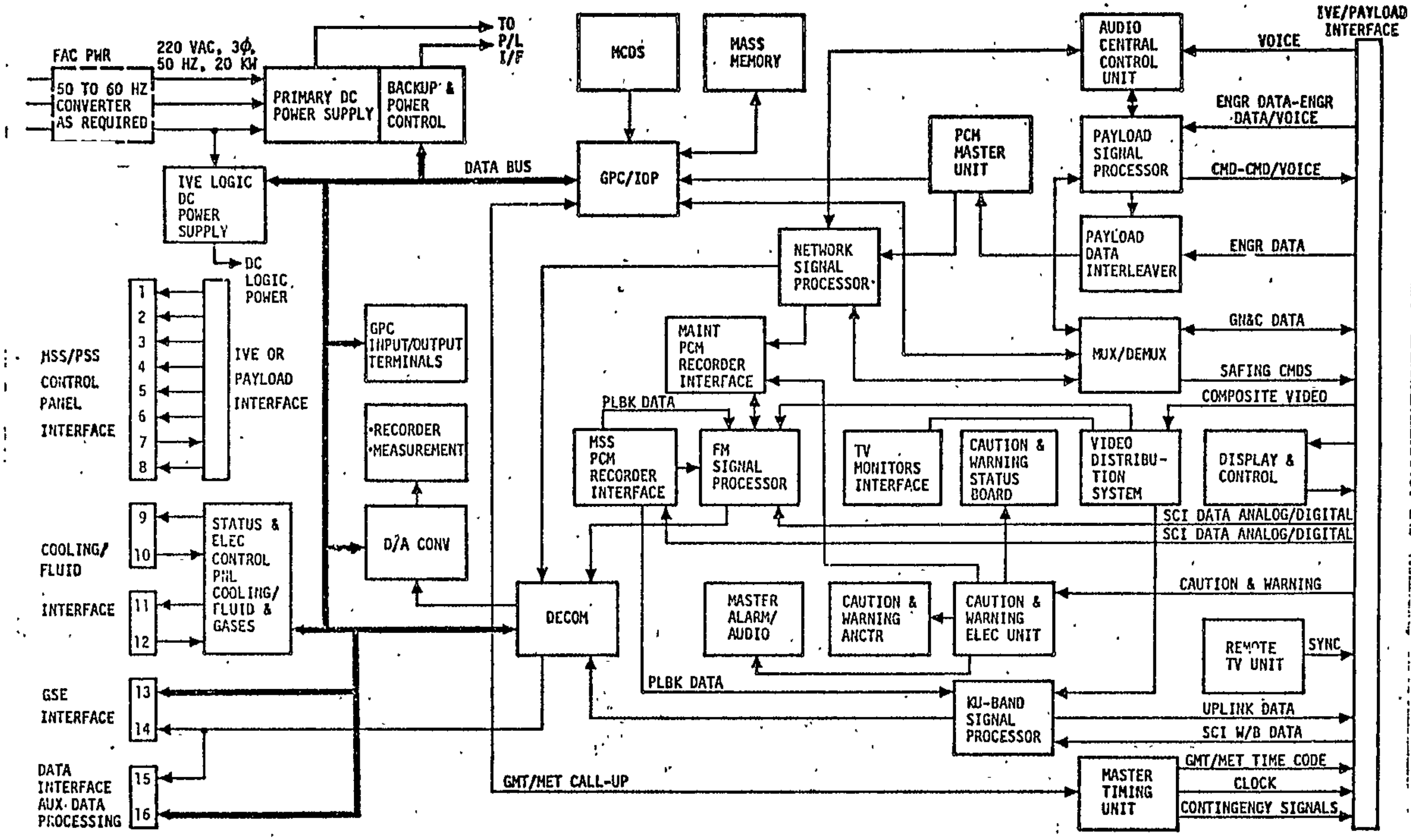

FIGURE 7-8 ELECTRICAL SUBSYSTEM OPTION I - BLOCK DIAGRAM

DISADVANTAGES (CONT)

HARDWARE AVAILABILITY SCHEDULE CONFLICTS WITH OV102

DELTA CONFIGURATION CONTROL PLAN REQUIRED

7.3.2 Electrical Subsystem - Option II

The Option II design approach emphasizes the use of commercial test equipment and Rockwell designed components (e.g., commercial digital voltmeters, frequency counters and signal formatters, decoders) as shown in Figure 7-9. Off the shelf commercial test hardware is used along with Space Division designed test hardware. Table 7.3 lists a typical selection of equipment which may be used for Option II. The advantages and disadvantages of Option II are:

ADVANTAGES

Operational Flexibility Changes Easily Accommodated

Inidividual Equipment Self-Check and Verification Capability

Easy Manual or Automated Operation

Minimum IVE Unique Equipment to be Developed

Spares Available

Supports Payload Software Verification

Minimal Schedule Conflict

DISADVANTAGES

Delta Configuration Plan Required

7.3.3 Electrical Subsystem Design Concept Selection

Table 7.4 summarizes the concept comparison showing advantages of design Option II over Option I leading to the selection of Option II for further design definition. As indicated, use of Option I requires equipment modifications to provide signal variation and self-test, troubleshooting and maintenance, this negates the sought for advantages of using Orbiter design equipment with respect to savings in design engineering, configuration managment, and maintenance and operations. Other advantages of Option II compared to Option I are: (a) built-in system test flexibility derived from use of modular design techniques

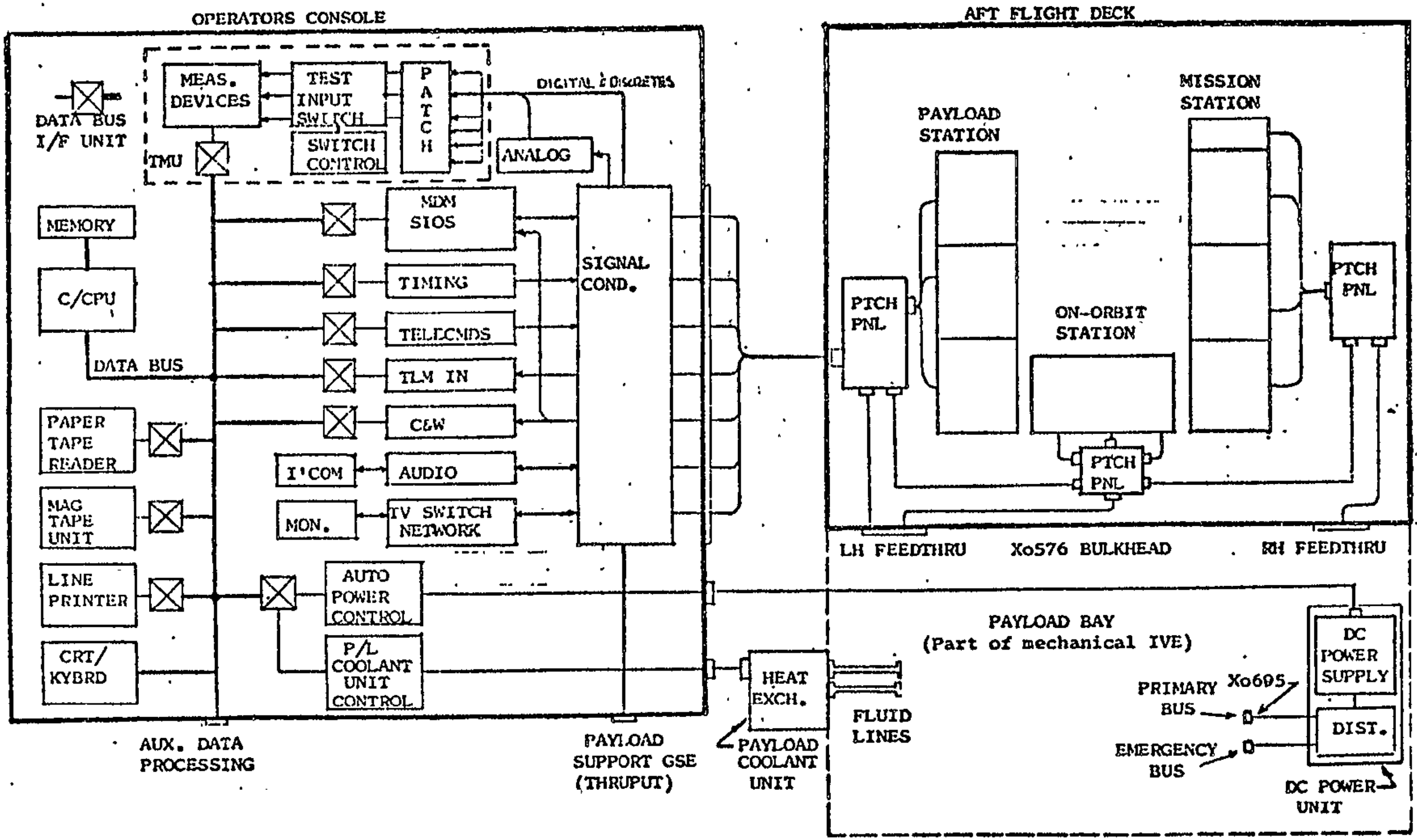

FIGURE 7-9 IVE ELECTRICAL SUBSYSTEMS FUNCTIONAL BLOCK DIAGRAM

TABLE 7.3 ELECTRICAL SUBSYSTEM OPTION II - TYPICAL EQUIPMENT

STANDARD TEST EQUIPMENT	MODEL
DATA PROCESSOR UNIT + I/O + P/S	ECLIPSE S200
MUX/DEMUX - SERIAL I/O SIMULATED I/F	ROCKWELL INT'L DEVELOPED
SIGNAL CONVERSION MODULES (AIE)	ROCKWELL INT'L DEVELOPED
DIGITAL VOLTMETER	S/D 7110A
FREQUENCY COUNTER	S/D 6151
TIMECODE GENERATOR	S/D 8120 (MODIFIED)
WAVEFORM ANALYZER	TBD
CONTROL & DISPLAY PANELS	ROCKWELL INT'L DEVELOPED
SWITCHING & PATCH PANELS	ROCKWELL INT'L DEVELOPED
LOGIC POWER SUPPLYS +28 VDC	TBD
DC LOGIC POWER SUPPLY +5 VDC	TBD
DC PRIMARY POWER SUPPLY	H/P CHRISTIE, CAL PWR
MAG TAPE UNITS	TBD
AFT FLIGHT DECK COMPONENTS	ROCKWELL INT'L DEVELOPED

TABLE 7.4 IVE ELECTRICAL SUBSYSTEM CONCEPTS COMPARISON

REQUIREMENT EVALUATION PARAMETER	OPTION I	OPTION II
• INTERFACE SIGNAL VARIATION OVER FLT RANGE	REQ EQUIP MODIFICATION	COMMERCIAL TEST EQUIP CAPABILITY
• OPERATIONAL FLEXIBILITY	HDWRE REDESIGN OR REPLACEMENT, DOES NOT PROVIDE ACCESS FOR TROUBLESHOOTING AND MAINTENANCE TYPICAL OF TEST EQUIP	MODULAR DESIGN WITH ASYNCHRONOUS DATA BUS, ACCOMMODATE SIGNAL INTERFACE CHANGES THROUGH SOFTWARE/ EXISTING HARDWARE
• SELF-CHECK	REQ ADDITIONAL EQUIP TO CHECK EACH INTERFACE	BUILT IN COMMERCIAL TEST EQUIPMENT
• HARDWARE AVAILABILITY	DEPENDENT ON SHUTTLE, SPACELAB IVE SCHEDULE CONFLICT	DEPENDENT ON DESIGN SPEC RELEASE, NOT DEPENDENT ON ORBITER HARDWARE DELIVERY SCHEDULE
• CONFIGURATION CONTROL	DELTA PLAN REQD	DELTA PLAN REQD
• COST (UNIT RECURRING) EXAMPLE:		
COMPUTER	GENERAL PURPOSE COMPUTER (GPC) 360K	MINI 40K
AUDIO	AUDIO CENTRAL CONTROL UNIT 120K	SIG. COND. SWITCH, HDSET 7K

(asynchronous data bus interfacing with commercial test equipment), (b) inidividual subassembly and interface self-check capability, (c) minimum IVE unique equipment required to be developed, (d) no spares conflict encountered with the Orbiter program due to use of IVE unique equipment, (e) minimal schedule conflict with Orbiter related hardware (only I/F hardware design data required for support of IVE).

Both Concepts I and II require delta configuration management control of changes to Orbiter interface characteristics, however, Concept II configuration management costs may be substantially lower than for Option I as performance may be varied for Option II mainly by procedural front panel switching and software changes. Also supporting the selection of Option II are the high initial hardware costs associated with Option I orbiter flight configuration hardware.

8.0 VERTICAL IVE CONCEPT

8.1 OBJECTIVE

The objective of this task was to develop an IVE design concept satisfying the requirements for verifying payload interface compatibility in the vertical position. The conceptual design approach utilized the Horizontal IVE as a point of departure, assessed its applicability for use in the vertical position, identified delta design requirements and defined delta design concepts. Potential applications other than payload interface verification were identified and their design impact on the IVE was investigated.

8.2 VERTICAL IVE DESIGN REQUIREMENTS AND CONSTRAINTS

In addition to the performance requirements imposed on the Horizontal IVE, the Vertical IVE shall satisfy the following:

1. Support critical access verification
2. Support ground operational procedures development and verification.
3. Use in horizontal position if required.
4. Facility interfaces - SAEF-1
    1) Airlock
    2) Overhead 25-ton crane for P/L handling and installation of P/L into IVE.
    3) Structural support from floor only.
    4) Facility power, chilled water and other fluids available at floor level.

8.3 VERTICAL IVE CONCEPT OPTIONS

Three Vertical IVE concepts were defined by NASA-KSC for determination of concept feasibility and cost deltas to the Horizontal IVE:

Concept I. IVE Electrical, Fluid Subsystems and MS, PS, OOS Elements Located at Floor Level.

Concept II. IVE Operators Console, Power Supply and Coolant Unit Located at Floor Level.

Concept III. All IVE Elements Located on Vertical Stack Location at near X_o 576.

The three concepts were evaluated to define design deltas to the Horizontal IVE. Horizontal IVE design areas impacted include: IVE equipment (operations console, power, payload cooling) location, aft flight deck, X_o 576 and X_o 1307 bulkhead assemblies, and IVE primary structure.

An initial investigation was performed providing a comparative analysis of the design impact on the Horizontal IVE for the three Vertical IVE concepts with results presented in Table 8.1. All three concepts require beef-up of the Horizontal IVE structure to support the payload, IVE "dead-load" and personnel. Concept III requires additional structural beef-up to support an X_o 576 work platform, operator's console, power unit, payload coolant unit and personnel. Concept III provided significant advantages over Concepts I and II with respect to electrical functions. A minimal change to the Horizontal IVE interconnecting cabling between (1) the operator's console and the AFD, and (2) DC power unit and mid-body primary power interface was required to reflect new equipment locations. Options I and II require approximately 80 feet of additional interconnecting cabling between the operator's console and power unit (at facility floor level) and payload interfaces at AFD and X_o service panels. The longer line runs result in significant changes in IVE performance with respect to line impedances, noise, cross talk, and signal attenuation. As a result, major redesign of interconnecting cabling is required with payload I/F impedance matching, signal condition, cabling isolation and remote monitoring required. Location of the DC power unit on the facility floor requires additional power conditioning equipment to compensate for voltage drop, higher source impedance, variation in ripple voltage levels, and the poor transient response characteristics exhibited by long line runs.

Modifications to the Horizontal IVE payload coolant unit and plumbing are minor for Concepts I and II requiring larger pump, increased line size up to payload I/F (not at I/F), line insulation and remote sensing of temperature, pressure, and flow rates.

Based on the above results, NASA-KSC selected Concept III for further concept development.

8.4 VERTICAL IVE DESIGN-CONCEPT III

Major design deltas to the Horizontal IVE involve only primary and secondary structures. Only minor changes are required to the electrical and fluid subsystems (changes in interconnecting cabling and fluid lines).

8.4.1 Primary Structure

A common primary structure design was used for both the horizontal and vertical IVE which reflects the design impacts of the Vertical IVE Option III (beef-up of structural member sizing and wall thickness) to meet column buckling and structural stability requirements.

TABLE 8.1. VERTICAL IVE CONCEPT COMPARISON SUMMARY

IVE SUBSYSTEM	CONCEPT I	CONCEPT II	CONCEPT III
PRIMARY STRUCTURE			BEEF-UP TO SUPPORT 19K LB PERSONNEL, IVE EQUIP & STRUCT.
OPERATORS CONSOLE	SIGNAL CONDITIONING AND REMOTE MONITORING REQD: HIGHER IMPEDANCE, NOISE, CROSSTALK, SIGNAL ATTENUATION	SAME AS OPTION I	NO IMPACT
DC POWER UNIT	POWER CONDITIONING, REMOTE SENSING REQD: HIGHER SOURCE IMPEDANCE RIPPLE VOLTAGE LEVELS, VOLTAGE DROP, POOR TRANSIENT RESPONSE	SAME AS OPTION I	NO IMPACT
PAYLOAD COOLANT UNIT	LARGER PUMP, REMOTE T, F, P SENSING, LINE SIZE AND INSULATION REQD:	SAME AS OPTION I	NO IMPACT

* CONCEPT III SELECTED BY NASA-JSC FOR FURTHER DEVELOPMENT.

8.4.1 Primary Structure (Cont'd)

Refer to Section 7 of this volume for a detailed discussion of the primary structure design. Primary structure design penalties incurred by the Horizontal IVE for a common vertical and horizontal structure are summarized in Table 8.2.

8.4.2 Secondary Structure

Major design deltas in secondary structure include complete redesign of (1) the aft flight deck (AFD) supporting structure, (2) the X_o 576 and X_o 1307 bulkheads and attachment to the primary structure in the Vertical Stack. Major additions include an X_o 576 work platform and a floor support stand.

8.4.2.1 Aft Flight Deck and X_o 576 Bulkhead Assembly

Using the facility overhead crane to install/remove payloads requires the capability to move the X_o bulkhead and other equipment in order to provide an unobstructed volume above the Vertical IVE Stack for clearance of crane operations (Figure 8-1). When the IVE is in a vertical position the X_o 576 bulkhead becomes a load-carrying member which must support the OOS enclosure and equipments, and operating personnel. The requirements above result in an integral aft flight deck and X_o 576 bulkhead assembly design as illustrated in Figure 8-1.

The AFD floor (in a vertical position) supports the MS and PS enclosures and related IVE and payload equipment. The AFD floor is attached to a load-carrying swing-up frame structure which supports flooring for access to the AFD, the AFD floor and the X_o 576 bulkhead. The swing-up structural assembly is hinged at two points to the primary structure cross beam at X_o 576.

8.4.2.2 X_o 1307 Bulkhead Assembly

The X_o 1307 bulkhead is a new design. The basic skin, stringer design of the Horizontal IVE is employed; however, the material was changed from aluminum to structural steel and requires beefing-up to support expected load within allowable deflection limits (Table 8.2).

8.4.2.3 X_o 576 Work Platform

The X_o 576 work platform is a new structural addition. A platform approximately 27 ft by 20 ft as shown in Figure 8-1 provides adequate room for the location of the IVE equipment and for conducting operations. The cantilevered platform is supported at the four corners with diagonal braces which tie into the primary structure at the mid-point of the upper mid-body section. The primary structure vertical and diagonal members distribute the loads to the primary structure longeron and lower closed members.

TABLE 8.2. HORIZONTAL IVE DELTA DESIGN PENALTY FOR VERTICAL OPERATION

STRUCTURE ELEMENT(S)	DESIGN DELTAS
LONGERON VERTICAL POST DIAGONAL POST LOWER CHORD	INCREASE WIDTH FROM 4 TO 6 INCHES
LOWER CHORD	INCREASE WALL THICKNESS 1/4 TO 3/8 INCHES
STIFFENER (LONG)	REPLACE ANGLE CLIP WITH INTEGRAL STRUCTURE STIFFENER MADE FROM BULB ANGLE 0.5 INCH THICK
CROSS BEAM	INCREASE DEPTH FROM 6 TO 10 INCHES
SECTION PLATES, BOLTING	INCREASE PLATE THICKNESS, BOLT SIZE AND PATTERN
X_o 1307 BULKHEAD ASSEMBLY	CHANGE MATERIAL TO STEEL INCREASE PLATE THICKNESS (0.06 TO 0.125 IN) AND FRAME MEMBER WALL THICKNESS (0.125 TO 0.25 IN)
AFT CREW STATION X_o 576 BULKHEAD	REDESIGN: USE MS, PS, OOS SECONDARY STRUCTURE AND X_o 576 BULKHEAD INTERFACES
SUPPORT STAND	ADD: NEW DESIGN

SD76-SH-0092

Rockwell International
Space Division

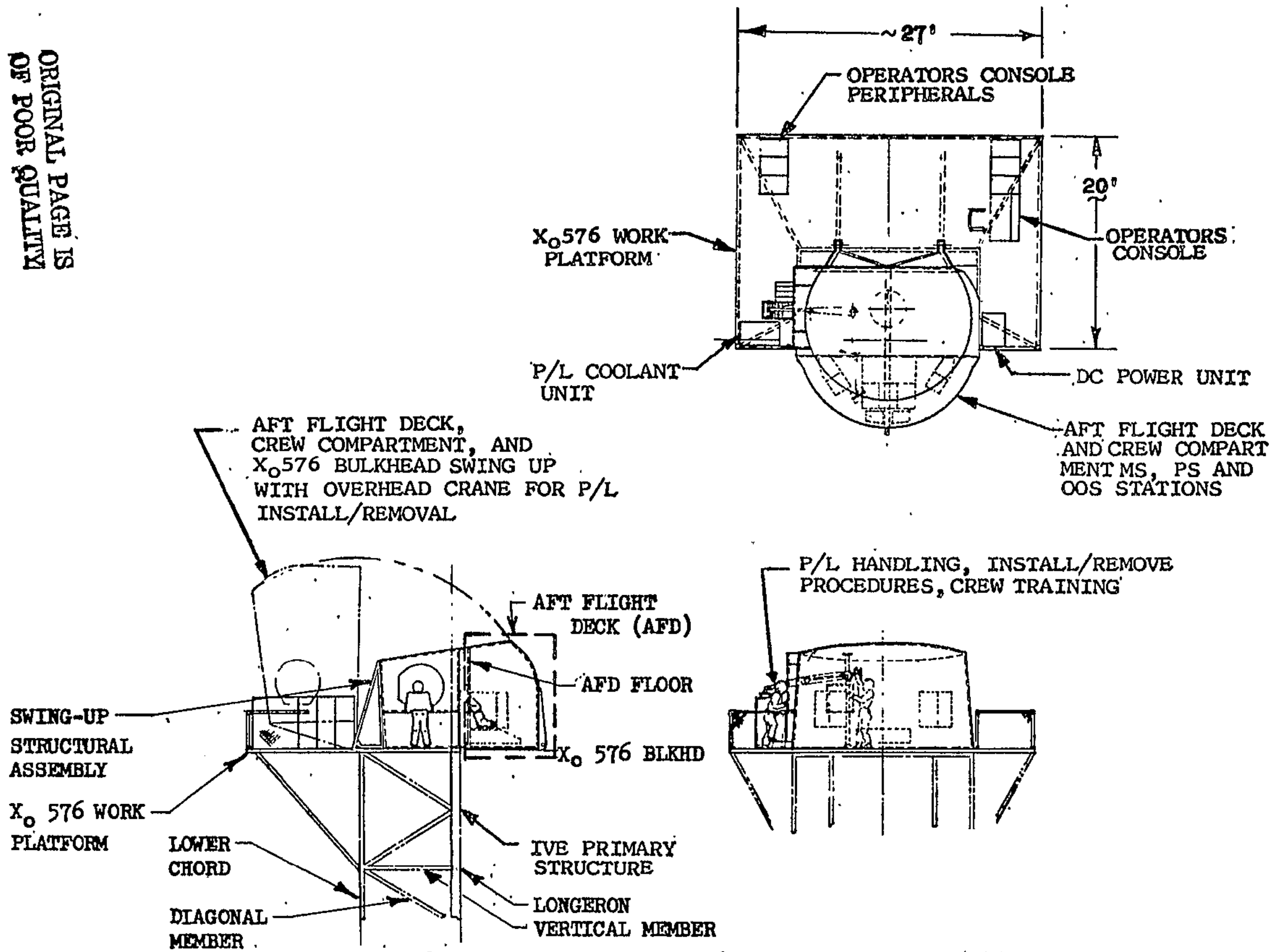

FIGURE 8-1 VERTICAL IVE X_o576 WORK AREA CONFIGURATION

8.4.3 IVE Support Stand

A stand is required to support the Vertical IVE at the desired height above the floor to provide access through/to the aft end of the X_o 1307 bulkhead and to provide clearance for the T-0 umbilical panels. A typical support stand design is illustrated in Figure 8-2. The IVE is bolted to the stand in the same manner as the mid-body section interconnections. Floor loading is distributed by triangular trusses through floor plates. The primary load is through the two vertical longerons. The maximum load at the floor may approach 70,000 lbs (65K P/L IVE structure, equipment, personnel and support stand all contribute to floor loading) at the positions shown in Figure 8-2. Using 30-inch square floor plates, the floor loading is approximately 80 psi, well within the SAEF-1 capability.

8.4.4 Electrical and Fluid Subsystems

No significant changes are required in the IVE electrical subsystems with the exception of new interconnecting cable assemblies between the operators console, power supply, coolant unit and the IVE aft flight deck. A cable disconnect interface is required between the elements located on the X_o 576 work platform and the AFD swing-up assembly. Rerouting of the fluid lines between the payload coolant unit and the IVE coolant interface is required.

Electrical and fluid interfaces between the IVE and the SAEF 1 facility at KSC include facility power, facility lighting, payload cooling water supply and drain, and gaseous nitrogen, other TBD for purging fluid lines.

8.5 VERTICAL IVE POTENTIAL APPLICATIONS

Three potential applications of the IVE to support payload integration (in addition to P/L I/F verification, functional checkout and mission simulation) were identified: (1) support critical access verification, (2) support development and verification of ground operational procedures and timelines, and (3) crew training.

8.5.1 Critical Access Verification

Utilization of the IVE mid-body liner will provide a replica of the Orbiter payload bay and may be used to support verification of access to the payload appendages, support points, cable interconnects, and P/L handling interfaces. The degree to which the IVE may be used for access verification is dependent upon the payload design, type of P/L handling equipment available(use of overhead crane may not reflect true payload handling interface as experienced on-line) and access workstands. Incorporation of a simulated aft crew cabin compartment shown in Figure 8-1 simulating the Orbiter hatch and access to the upper AFD would permit verification of access to equipment located in the AFD.

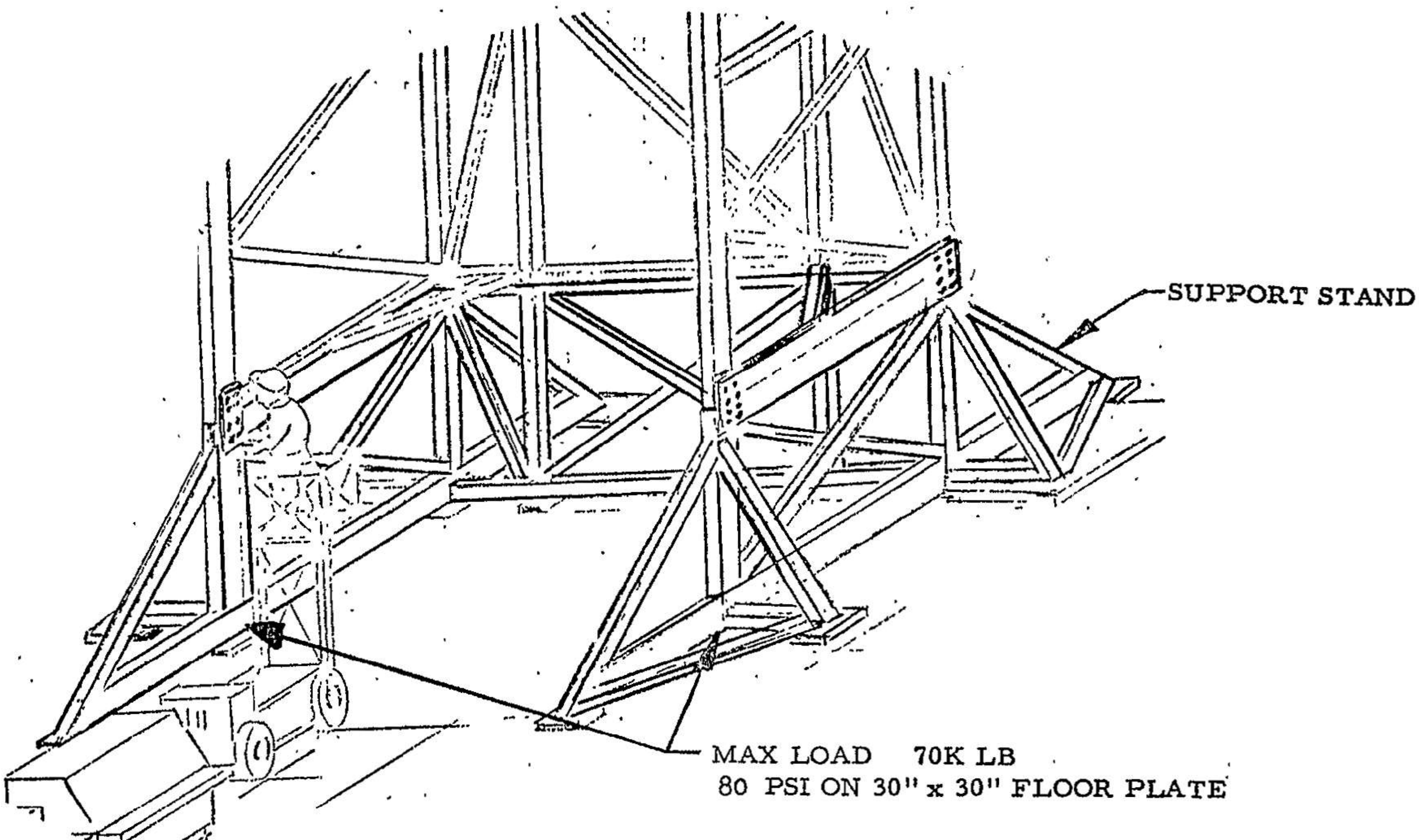

FIGURE 8-2 VERTICAL IVE SUPPORT STAND DESIGN CONCEPT

8.5.2 Ground Operation Procedures Development and Verification

Use of the IVE mid-body to develop and verify payload (and related support equipments) installation/removal procedures and timelines is limited by the fidelity of the payload handling device. Using the overhead crane for payload handling precludes verification of payload handling and installation/removal procedures into the payload bay.

The simulated aft crew compartment (shown in Figure 8-2) may be configured to represent a high fidelity replica of the Orbiter cabin with respect to the installation/removal of payload elements and their servicing in a vertical stack position. With the availability of on-line payload handling equipment the IVE would support the detailed development and verification of the payload installation/removal, associated timelines, and support ground crew training for these operations. The IVE may also support flight crew training with respect to the operation of the payload. See Section 10 of this volume for additional comments on IVE potential applications.

8.5.3 Vertical IVE Split Stack Configuration

Of interest to NASA-KSC was the capability of the IVE to be used in a split stack configuration as shown in Figure 8-3. The modular design approach utilized for the IVE allows use of either 1, 2 or 3 mid-body sections (each 20 feet long) with the X_o 576 work area in a vertical stack configuration since the primary structure was designed for the maximum load condition using common member sizing throughout the mid-body. Additional base support stand(s) would be required. Dependent upon the specific usage, interconnecting payload and IVE cabling between the split stacks would require structural support.

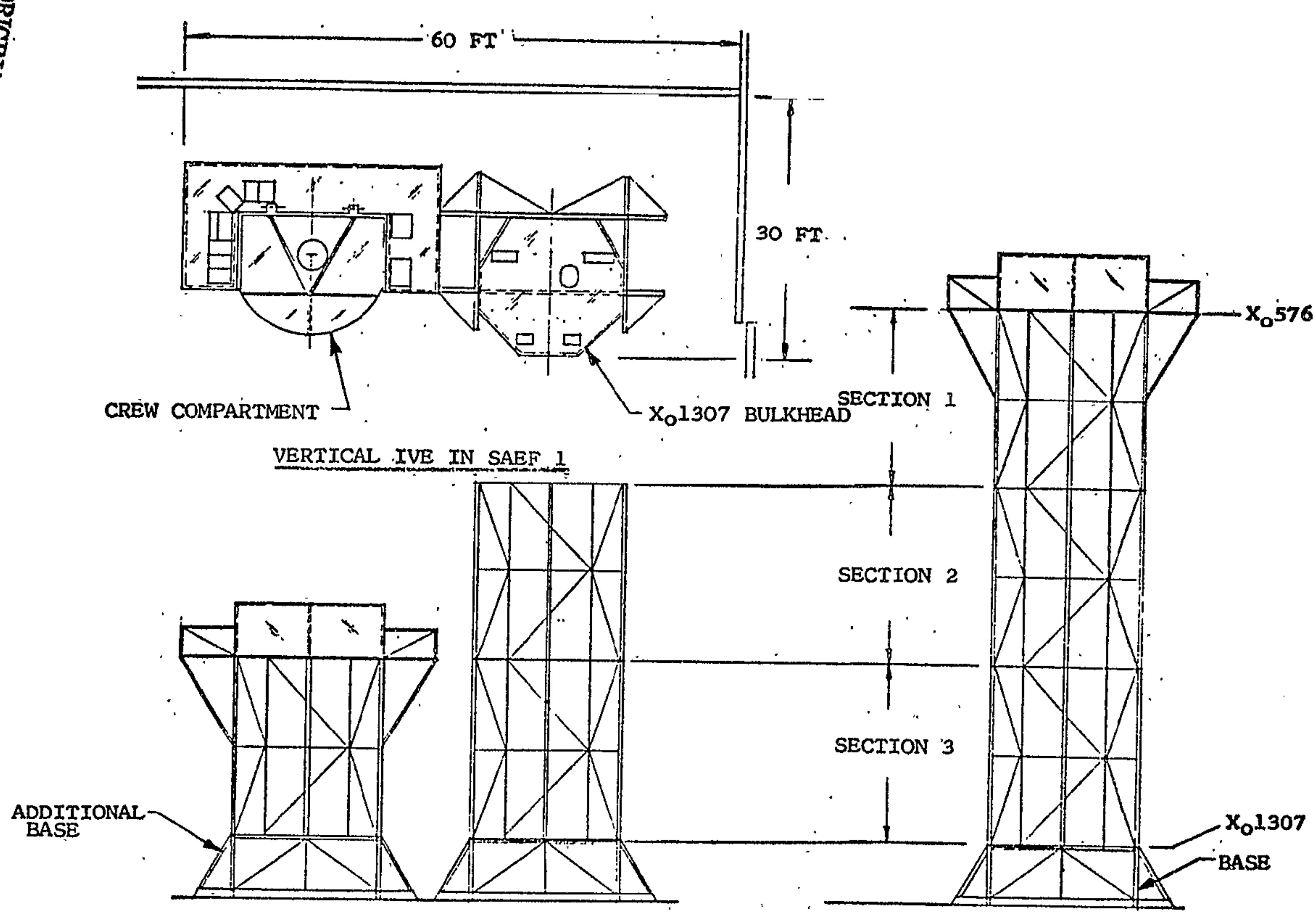

FIGURE 8-3 VERTICAL IVE SPLIT STACK CONFIGURATION

9.0 SHUTTLE/PAYLOAD INTEGRATION ANALYSIS

9.1 OBJECTIVE

The primary objective of this Shuttle/payload integration analysis is to identify potential applications for the IVE to support payload integration through its development stage up to launch. The Space Transportation System (STS) introduces a new concept in which the propulsive stage (Shuttle) not only delivers and returns payload(s) to and from orbit but also may provide major support to the payload with respect to power, thermal control, commands, housekeeping data, payload data transfer, etc. during combined Shuttle/payload operations. As a result of the Shuttle supporting payload operations, the payload requires knowledge concerning the Shuttle Orbiter payload accommodations at earlier stages of payload development prior to the physical and functional bringing together (mating and checkout of the payload installed in the Orbiter).

This analysis is an initial investigation representing an objective analysis by the Space Division of Rockwell International of payload development data provided by the NASA to (1) develop at a top level, payload integration flow processes representing the general class of payloads, (2) determine the degree of Orbiter interface (I/F) knowledge required by the payload during the total payload integration process, and (3) identify potential applications of the IVE in support of the payload integration process to satisfy requirements as defined in (2) above.

A secondary objective was to develop evaluation criteria to support Shuttle Orbiter/payload integration trade studies. Space Division was specifically excluded by the NASA from conducting payload integration trade studies as a part of this analysis.

9.2 GROUND RULES AND ASSUMPTIONS

Ground rules and assumptions governing this analysis are:

- Payload data provided by NASA/JSC
- The broad spectrum of payloads will be represented by five payload configurations selected by NASA based on results of the payload data analysis.
- Payload baseline data processing (integration and test operations) reflects objective analysis of NASA supplied payload data.

- Payload data processing options shall exercise the extremes of payload integration responsibility (maximum integration prior to arrival at launch site and, maximum integration after arrival at the launch site), to a sufficient level to identify IVE potential applications.

- The Space Shuttle Payload Interface Verification Document JSC 07700-Vol. XIV-PIV-01 shall apply to the payload integration analysis.

9.3 ANALYSIS

The analysis was conducted as shown in Figure 9-1. An analysis of the data base resulted in the selection of the following five payloads as being representative of the general payload class: Solar Maximum Mission (SMM), Module with Pallet (Spacelab), Solar Physics Dedicated Mission, Large Space Telescope (LST), and IUS/Mariner Jupiter Orbiter (IUS/MJO).

Sources of data used for this analysis include:

<u>Module With Pallet (Spacelab)</u>

SD74-SA-0156 SUIAS (Rockwell)
Spacelab Ground Operations Study (MSFC)
PGOR Processing Flow (Rockwell)
Spacelab Payload Accommodation Handbook (ESRO)
NASA Supplied Processing Flow Chart

<u>Pallet Only (Solar Physics)</u>

Space Shuttle Payload Description-DSSM
SD74-SA-0156 SUIAS (Rockwell)
PGOR Processing Flow (Rockwell)
Spacelab Payload Accommodation Handbook (ESRO)
ASP Integration Flow from GSFC

<u>Solar Maximum Mission (SMM)</u>

Phase "B" Study Solar Maximum Mission
Space Shuttle Payload Description - SMM
PGOR Processing Flow (Rockwell)

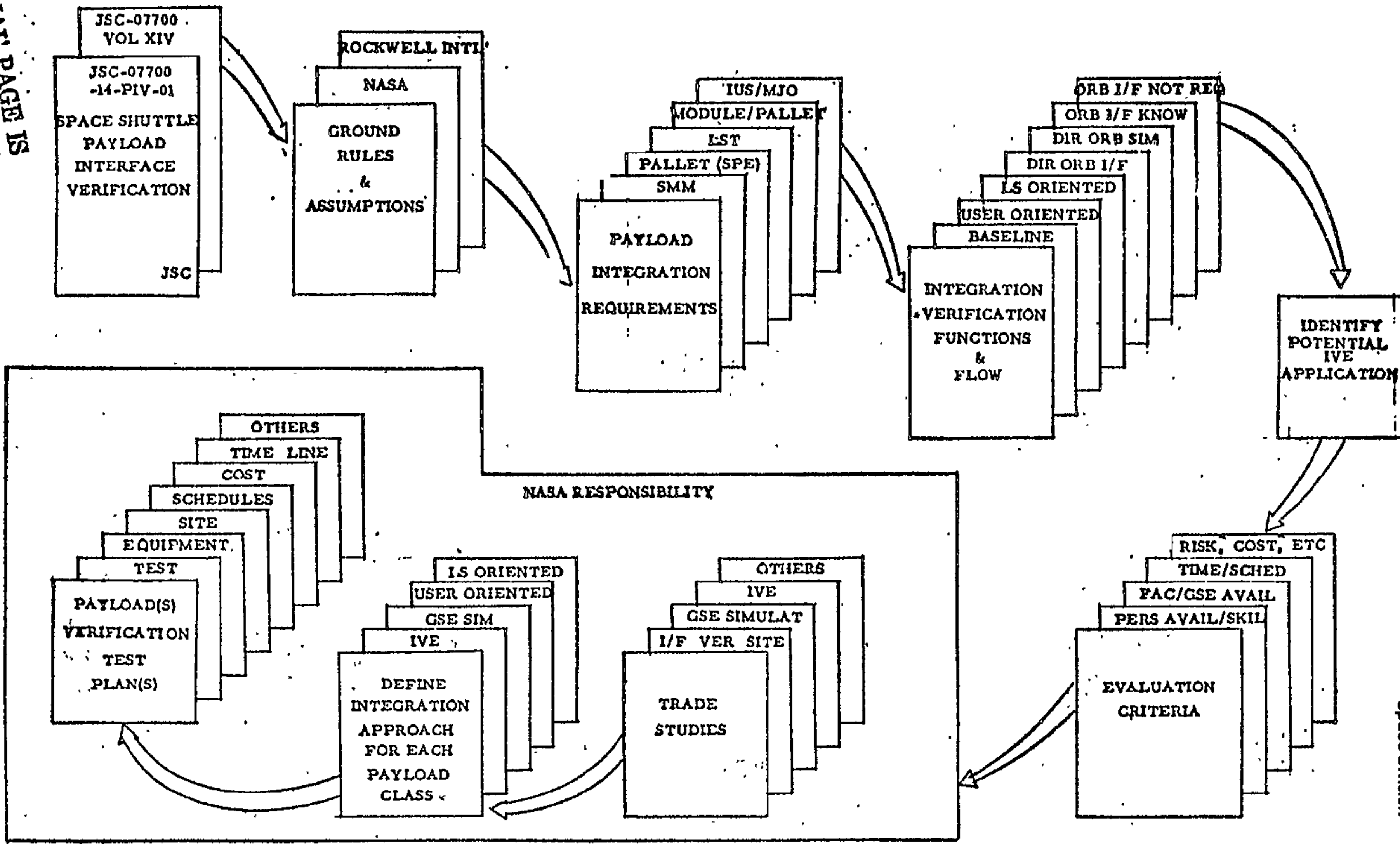

FIGURE 9-1 SHUTTLE/PAYLOAD INTEGRATION ANALYSIS STUDY LOGIC

Large Space Telescope (LST)

Sect 5 SMM and LST Integration and Test (Lockheed)
Space Shuttle Payload Description - LST
PGOR Processing Flow (Rockwell)

Mariner Jupiter Orbiter/IUS

MJO Planetary Study
Space Shuttle Payload Description - MJO
KSC IUS Processing Flow Chart Dated 9-25-75
IUS Studies (Solid Propellant)
PGOR Processing Flow (Rockwell)

The Payload Integration functional flow block diagrams based on an objective analysis of the payload user data provided by the NASA are identified as the baseline. Two payload integration flow options were also developed, (1) user site oriented-maximum integration functions accomplished prior to delivery to the launch site and (2) launch site oriented-minimum integration functions accomplished prior to delivery to the launch site. The basic differences between the three flow options are shown in the top level flow diagrams in Figure 9-2.

Figure 9-3 shows a portion of the SMM payload integration functional flow block diagram illustrating the scope and degree of definition of payload integration functions accomplished in this analysis.

Four degrees of Orbiter interface knowledge were defined as follows:

1. No Orbiter I/F knowledge required.
2. Orbiter I/F knowledge required - data as defined in the JSC 07700 - Volume XIV Payload Accommodations
3. Direct Orbiter Simulation required - actual physical simulation of an I/F, physical and/or functional (mechanical form, fit and electrical function - power and signals).
4. Direct Orbiter I/F - require payload installation into a flight Orbiter (Level I integration and preflight preparation and checkout).

Each of the functional blocks identified in the FFBD's (Figure 9-3) are number coded to reflect the above degrees of Orbiter I/F knowledge.

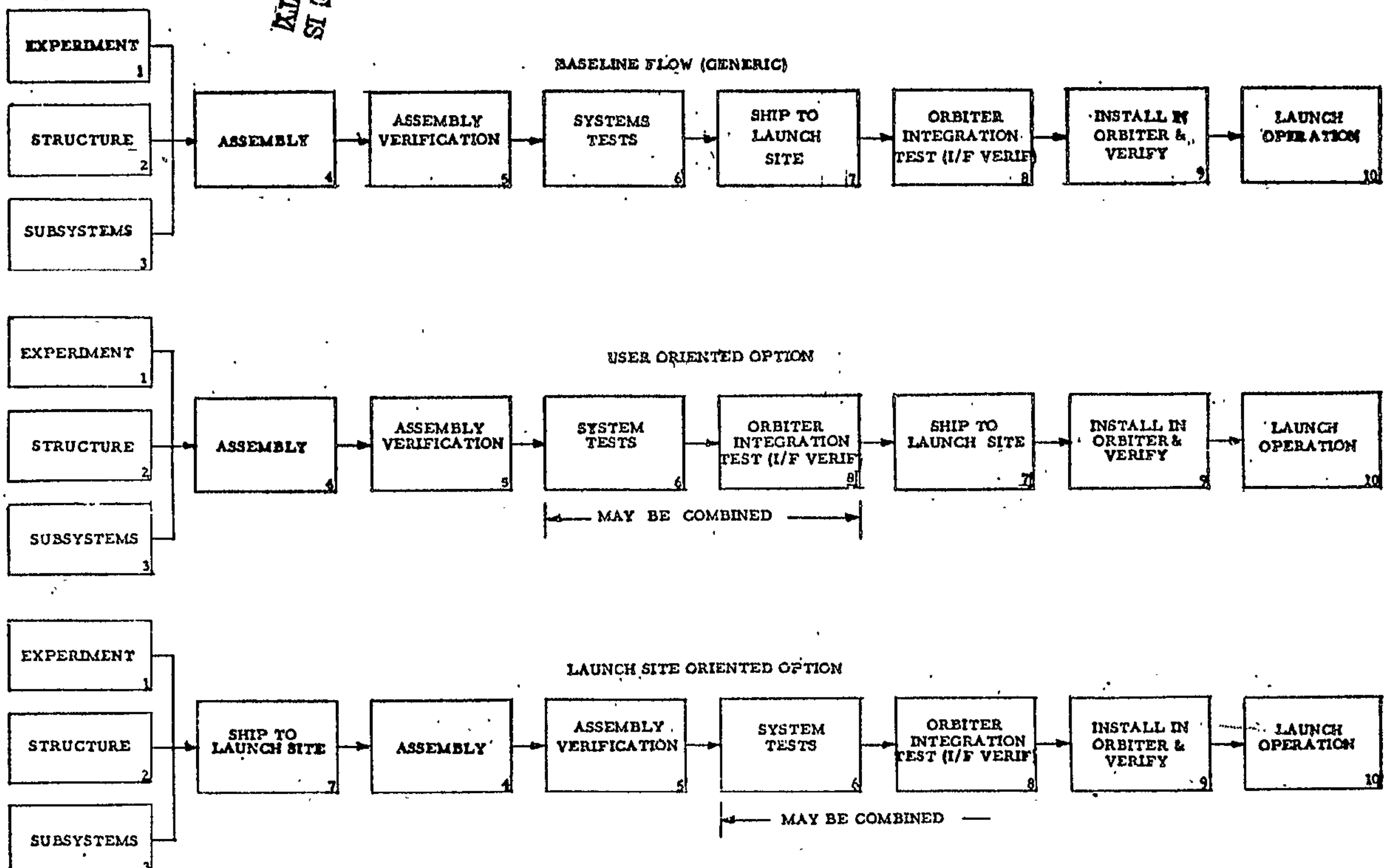

FIGURE 9-2 PAYLOAD INTEGRATION FLOW OPTIONS

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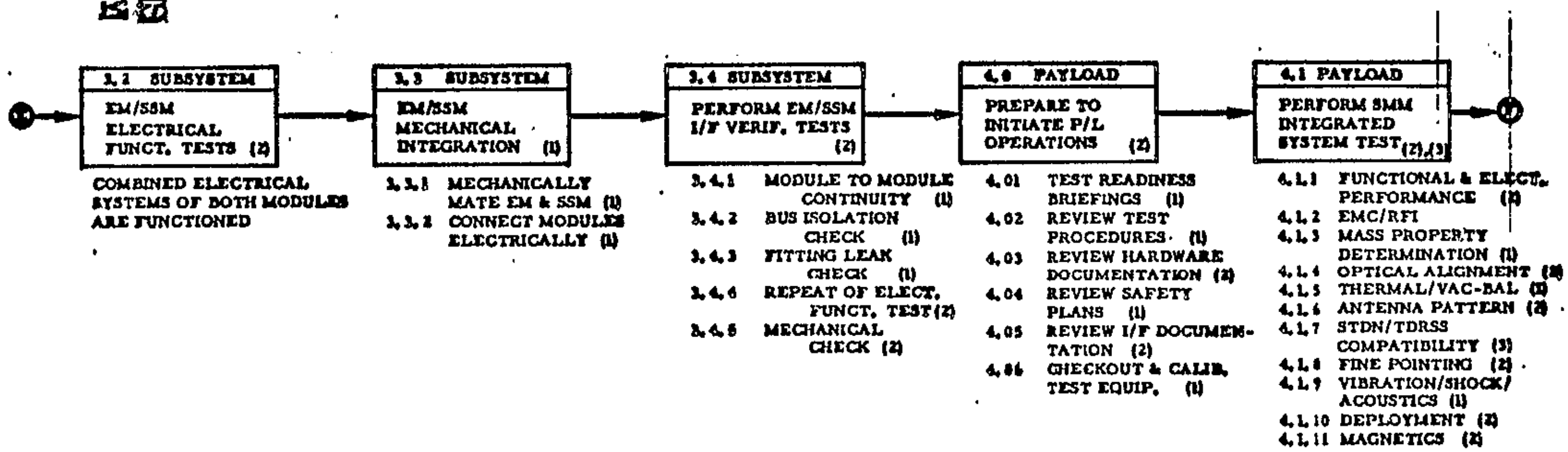

* (1) ORBITER I/F KNOWLEDGE NOT REQUIRED
(2) ORBITER I/F KNOWLEDGE REQUIRED
(3) DIRECT ORBITER FUNCTIONS SIMULATED
(4) DIRECT ORBITER I/F

FIGURE 9-3 EXAMPLE - SOLAR MAXIMUM MISSION (SMM) FUNCTIONAL FLOW BLOCK DIAGRAM

The optional payload integration processes (user site oriented and launch site oriented) showing deltas to the baseline FFBD's are defined in tabular form as illustrated in Table 9.1. The first column block numbers identify the specific block in the FFBD. The description column identifies the hardware involved, functions performed and operation level (subsystem and system payload makeup and cargo). The baseline location column by definition (from NASA data base) is either at the user site (payload contractor and/or Agency) or launch site. The X's in the Option I User Oriented column identify the FFBD functional blocks applicable to user site operation. X's in the Option II Launch Site Oriented column identify the FFBD functional blocks which are applicable at the launch site. Payload and Orbiter GSE simulation equipment requirement identification and potential IVE application are indicated by X's in the two checkout/test equipment columns. The special facility column indicates requirement for thermal vacuum, vibration, acoustics, EMI/EMC, etc. facilities required to perform a specific payload function. The remarks column provides clarification comments, identifies functions that may be performed at either User or Launch Site or required at both sites and identifies functions requiring additional trade studies to determine the preferred site to perform a specific function. The complete description of the five selected payload baseline and optional FFBD's are included in Appendix C.

Advantages and disadvantages of the three flow options which are recognized during the study are summarized in Table 9.2. A detailed analysis is required to evaluate these advantages and disadvantages in terms of the evaluation criteria discussed in Section 9.4.

9.4 TRADE STUDY EVALUATION CRITERIA

In the final analysis; implementation of trade study results is governed by economic and social-political considerations. The evaluation criteria developed by Space Division considered only those factors contributing to the ultimate determination of $ cost. Table 8.2 shows the cost contributing categories and the associated criteria which must be converted to quantifiable values with an associated risk factor (confidence level) in order to perform meaningful payload integration trade studies. As indicated, the $ column must also be tempered by the absolute schedule time impact. For some payloads and integration functions schedule time is absolute and dictates the cost. For other payloads and integration functions time may be traded against cost. Associated with the time and $ is the risk factor or degree of confidence (R column in Table 9.3). Development of submatrices applying $, T, and R against each function identified in the FFBD's and subsequent summation is required to arrive at an optional integration flow on a single payload basis. The data may then be used to support relative merits of non-

TABLE 9.1 EXAMPLE - SOLAR MAXIMUM MISSION (SMM) INTEGRATION AND CHECKOUT MATRIX

BLOCK NO.	DESCRIPTION	INTERFACES				CHECKOUT/TEST EQUIPMENT		SPECIAL FACILITY	REMARKS
		* I/F KNOWLEDGE	BASELINE LOCATION	OPTION 1 USER ORIENTED	OPTION 2 LAUNCH SITE [illegible]	[illegible] STE	IVE		
4.0	Prepare to initiate payload operations	(2)	User		X				
4.01	Test readiness briefings	(1)		X	X				
4.02	Review test procedures	[illegible]		X	X				Both sites
4.03	Review hardware documentati[illegible]	(2)		X	X				
4.04	Review safety plan[illegible]	(1)		X	X				
4.05	Review i[illegible]entation	(2)		X	X				
4.06	[illegible]out & calibrate test equipment	(1)		X	X	X	X		
4.1	Perform SMM integrated system tests	(1), (2), (3)		X	X	X	X		
4.1.1	Functional & electrical performance	(2)		X	X	X	X		
4.1.2	EMC/RFI tests	[illegible]		X	X				Monitor EMI/RFI during funct. tests
4.1.3	Mass propert[illegible]	(1)		X				X	Special facility
4.1.4	[illegible]	(2)		X	X	X	X		Both sites
[illegible]	[illegible]/vac balance	(1)		X		X		X	Special facility required
[illegible]	Antenna pattern	(2)		X	X	X	X		Both sites
4.1.7	STDN/TDRSS compatibility	(3)		X	X				Direct link communications
4.1.8	Fine pointing	(2)		X	X	X	X		Both sites
4.1.9	Vibration/shock/acoustics	(1)		X	X	X		X	Special facility required
4.1.10	Deployment	(2)		X	X	X	X		
4.1.11	Magnetics	(2)		X		X			

* (1) ORBITER I/F NOT REQUIRED
(2) ORBITER I/F KNOWLEDGE REQUIRED
(3) DIRECT ORBITER FUNCTIONS SIMULATED
(4) DIRECT ORBITER I/F

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TABLE 9-2 PRELIMINARY CONSIDERATIONS - PAYLOAD PROCESSING OPTIONS

OPTIONS	ADVANTAGES	DISADVANTAGES
1. BASELINE	1. MINIMUM USER SUPPORT AT LAUNCH SITE (MANPOWER COST REDUCTION) 2. BEST BALANCE OF PERSONNEL & FACILITIES 3. MINIMAL RISK OF FLIGHT EQUIPMENT FAILURE DURING LAUNCH AND FLIGHT	1. DUPLICATION OF TEST/CHECKOUT EQUIPMENT (IVE/GSE SIMULATORS) 2. SOME TESTING/CHECKOUT REDUNDANCY 3. LONGEST ELAPSED TIME FROM DEVELOPMENT TO LAUNCH 4. COULD IMPACT 160 HRS TURN AROUND TIME 5. INCREASED HANDLING RISK 6. DECENTRALIZED MANAGEMENT OF P/L INTEG.
2. USER SITE ORIENTED	1. MINIMUM TEST/CHECKOUT REDUNDANCY 2. MINIMUM OF MAJOR INTEGRATION/CHECKOUT EQUIPMENT 3. MINIMUM I/F CHECKOUT AT LAUNCH SITE 4. MINIMUM TURN AROUND TIME FOR FLIGHT EQUIPMENT REPAIR/REPLACEMENT 5. MINIMUM IMPACT ON LAUNCH SITE SCHEDULES 6. REDUCED HANDLING OPERATIONS	1. INCREASED FLIGHT EQUIPMENT RISK AT LS A. BECAUSE OF HANDLING & SHIPPING B. LACK OF COMPREHENSIVE I/F TESTING AFTER SHIPMENT 2. POSSIBLE INCREASED TESTING AT P/L ORBITER MATING 3. POSSIBLE IMPACT ON ORBITER ON-LINE TURN AROUND SCHEDULE 4. POSSIBLE LOGISTICS IMPACT 5. POSSIBLE INCREASE OF PLANNED MANPOWER 6. INCREASED STATION SET UTILIZATION (NON SCHEDULED EQUIPMENT) 7. DECENTRALIZED MANAGEMENT OF P/L INTEGRATION
3. LAUNCH SITE ORIENTED	1. MINIMUM TEST/CHECKOUT REDUNDANCY 2. MINIMUM OF MAJOR INTEGRATION/CHECKOUT EQUIPMENT 3. MINIMUM HANDLING AND TRANSPORTATION OF MATED PAYLOAD 4. HIGH I/F VERIFICATION CONFIDENCE LEVEL 5. CENTRALIZED MANAGEMENT OF PAYLOAD INTEGRATION 6. P/L PROCESSING EXPERIENCE/EFFICIENCY 7. POSSIBLE PAYLOAD OPERATION COST REDUCTION 8. POSSIBLE MANPOWER COST REDUCTION	1. INCREASED USER SUPPORT AT LAUNCH SITE 2. POTENTIAL FACILITIES/MANPOWER SCHEDULING IMPACT 3. POTENTIAL FLIGHT EQUIPMENT SCHEDULING IMPACT 4. POSSIBLE IMPACT ON ORBITER ON-LINE TURN AROUND SCHEDULES

TABLE 9.3 PAYLOAD INTEGRATION TRADE STUDY EVALUATION CRITERIA

CATEGORY	CRITERIA	BASELINE			OPTION 1 USER SITE ORIENTED			OPTION 2 LAUNCH SITE ORIENTED		
		WEIGHT FACTOR			WEIGHT FACTOR			WEIGHT FACTOR		
		$	T	R	$	T	R	$	T	R
PERSONNEL	AVAILABILITY SKILL MIX NUMBER OF PERSONNEL RELOCATION WITH PAYLOAD CREW DUPLICATION/DIFFERENT SITES/ UNION IMPACT									
	SUB-TOTAL									
FACILITIES	AVAILABILITY Δ FACILITY REQ. (NEW/MOD) FACILITY IMPACT: CLEANLINESS PROTECTION FROM HAZARDS ACCESS TO SOURCE OF TRANSPORT ENVIRONMENT LEVEL OF ASSEMBLY/PROCESSING REQ'D FACILITIES MAINTENANCE									
	SUB-TOTAL									
GSE	AVAILABILITY Δ GSE REQ. (NEW/MOD) GSE IMPACT LEVEL OF ASSEMBLY/PROCESSING REQ'D SIMULATORS REQUIRED HANDLING EQUIPMENT GSE MAINTENANCE									
	SUB-TOTAL									
OPERATIONS	DEGREE OF TESTING AND CHECKOUT (PHILOSOPHY) TRANSPORTATION AND HANDLING DEGREE OF SIMULATION PAYLOAD ACCESS FOR MAINTENANCE AND REPAIR SENSITIVITY TO PERTURBATIONS STANDARDIZATION OF INTERFACE VERIF. DEGREE OF SYSTEMS INTERFACE VERIF. SCHEDULE IMPACT/TIMELINES									
	SUB-TOTAL									
MANAGEMENT	PLANNING/SCHEDULING CONFIGURATION MANAGEMENT DOCUMENTATION MANAGEMENT GFE COORDINATION LOGISTICS ADMINISTRATION									
	SUB-TOTAL									
	GRAND TOTAL									

$ - ABSOLUTE COST
T - SCHEDULE TIME
R - RISK

NOTE: FOR EACH PAYLOAD, DETERMINATION OF $, T AND R REQUIRES DEVELOPMENT OF SUB-MATRICES APPLYING THE CRITERIA AGAINST EACH FUNCTION IDENTIFIED IN FFBD AND SUB-SEQUENT SUMMATION.

optional payload integrating flow for one or more payload classes in order to achieve an optional payload integration process for the total spectrum of Shuttle Orbiter/Payloads.

10.0 POTENTIAL APPLICATIONS FOR THE IVE

The results of the Shuttle/Payload Integration Analysis identified various potential applications for the IVE primarily associated with the verification of payload compatibility with the Shuttle. In order to realize the maximum potential for the IVE, it is necessary to determine whether or not the IVE or portions of it may be used for their applications. As a first step, this study identified payload development and integration activities which require various degrees of knowledge of the Orbiter payload accommodations. Those activities involving the simulation of the Orbiter function were assessed for potential of the IVE to provide that function (see Section 9). The potential applications for the IVE to support the Shuttle/Payload development and integration process as identified in the study include:

Use as a Design Tool to Support Verification of

- Access GSE
- Clearances
- Power Distribution
- TV Camera Locations
- Payload Bay Lighting
- Payload Design/Development (at Interface)

Use as a Manufacturing Aid/Production Tool

- Cable and Fluid Line Mockup
- Flight Cable Buildup
- Flight Fluid Line Assembly
- Payload Structural I/F's in Payload Bay and Aft Flight Deck

Use for Procedures Development

- Payload Installation and Removal
- Checkout
- EVA
- Mission Timeline and Evaluation

Use for Training Aid

- Flight Crew-Payload Relation Operations
- Ground Crew

Additional analysis is required to determine the desirability of using the IVE for the above applications. Detailed requirements need to be defined, IVE design implications and associated costs/schedule data needs to be developed, and trade studies performed to assess other techniques/equipment usage to accomplish the above functions.

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

The Horizontal IVE concept developed in this study represents a first attempt to define a standard integration device to support the verification that a payload/cargo is compatible with the Shuttle/Orbiter prior to on-line payload installation into the Orbiter. The initial intent of the study was to define a low cost device capable of verifying Orbiter-to-payload interface compatibility. During the study the performance requirements were expanded which led to the development of the IVE as an integration device capable of verifying not only interface compatibility but also to support payload functional performance and mission simulation for STS cargo as well as single payloads.

The IVE is a stand alone non-facilitized device which verifies Orbiter-to-cargo (payloads) interfaces within the following limitations imposed due to high cost, impact on facility, and duplication of existing under-development, or planned capabilities within the STS program: EMI/EMC restricted to payload conducted interference (Orbiter sources not included), software verification limited to timing and sizing checks (complete verification requires an Orbiter General Purpose Computer), payload bay environment simulation limited to payload active thermal control (dynamics, temperature,humidity and purge capability not included), passive RMS (complex facility interface and/or driver/control mechanism required for viable simulation), and non-active fluid interfaces (restricted to pressure leak checks). The IVE design does not preclude the upgrading of its capability to alleviate the above limitations at additional cost.

At the time this study was conducted, a complete set of payload integration requirements did not exist. The IVE concept reflects the requirements as specified in Section 5.0 of this Volume which originated from NASA, JSC (assumed role of STS integrator to define requirements), GSFC (representing free flyer and multi-mission spacecraft requirements), MSFC (Spacelab requirements) and KSC (launch site requirements).

The following conclusions resulted from this study:

1. The IVE can be used to support payload development, functional checkout, acceptance testing and mission flight simulation.

2. The IVE may be used to support development and verification of payload ground operational procedures and

operational timelines for payload installation and removal, and access when payload is installed in Orbiter.

3. The IVE may be used as a design aid tool with respect to location of payload lighting and camera locations, payload cabling and fluid line routing and their attachment.

4. The IVE may support ground and flight crew training.

5. A common structural design approach for horizontal and vertical IVE operation is feasible with minimal penalty.

6. IVE electrical subsystem design utilizing commercial test equipment with a minimum of Orbiter non-flight qualifiable design hardware provides (1) IVE maximum operational flexibility, (2) an IVE configuration independent of Orbiter flight hardware and its scheduled availability, and (3) least cost.

7. The IVE as designed is a high fidelity replica of the Orbiter payload accommodations providing a standard interface and is not dependent upon payload design. As such, the IVE design provides a inherent operational flexibility to support payload integration for new missions (and associated spacecraft) not presently defined in the STS mission model. The IVE modular design also allows for the most cost effective approach to expand the IVE capabilities on an as needed basis, e.g., tailor the IVE configuration to the user needs in a time phased basis to support the existing (at the time) Space program.

11.2 RECOMMENDATIONS

The following tasks are required to be accomplished in order to provide a firm basis for initiating development of payload integration devices:

1. Requirements - An STS systems requirements analysis is required representing all STS system elements (payloads, Orbiter and launch site). The general requirements governing the IVE study (specific and assumed) represented the best available information.

The STS program development has matured since the IVE study inception. Specific cargo/payload integration requirements need to be developed for the launch sites and payload user site. These requirements must reflect a division of payload integration activities between the launch site and payload developer sites such that a cost effective STS payload integration process is accomplished.

2. Requirements Sensitivity Analysis - The payload integration requirements must reflect the anticipated "real world" Orbiter cargo consisting of mixed payloads. A requirements sensitivity analysis is required to assess impact on varying integration processes with respect to site location, traffic flows, traffic density and identify critical requirements driving integration equipment design and cost.

3. STS System Operation Performance Trades - STS system performance trades need to be performed to verify optional system operations of the STS. Trade impact of various traffic models on payload integration equipment requirements (type, inventory, facilities including relaxing the Orbiter turnaround times) to determine the lowest cost per flight commensurate with anticipated future space budgets.

4. IVE Potential Applications - Conduct an intensive investigation of the degree of commonality/integration of the cargo/payload integration devices with the workstands at the launch site, payload handling and transport devices and GSE/Test equipment at launch site and payload developer sites. Also investigate other applications of the IVE or CITE (NASA/KSC version of IVE-Cargo Integration Test Equipment) to determine desirability of a common device to support payload ground support operations (procedures and timeline development and verification), flight crew training and other potential applications identified in Section 10.0 of this volume.

Design commonality of STS payload GSE, Orbiter payload integration devices, training aids, etc., may reflect significant savings over the operational era of the STS program. Significant cost contributors to the operational phase of the STS are configuration control,

operations and logistics (inventory and handling) management. As hardware design commonality on a program increases, the operational costs decrease due to savings in the reduced level of program management operations for configuration management and logistics support for a fewer number of equipment items.

IVE Design Evaluation - Reassess applicability of the IVE design to meet updated set of STS payload integrations requirements (include DoD requirements). Identify delta design impact and associated costs and schedule impact.

Payload Integration Device (IVE) - Design of payload integration equipment must incorporate flexibility in performance to satisfy the ever changing requirements as the STS program matures. Consideration must be given to modular designs providing a systematic, cost effective method for updating payload integration equipment capability at respective user locations on a time schedule "in tune" with the STS program requirements. Flexibility of performance must be inherent in the design of the payload integration equipment to respond to new space missions (presently unknown) and everchanging responsibilities and requirements of payload users during the STS program operational life.